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WEEKLY 17 September 2022

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New Scientist

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Megalithic Malta: Temples, fortifications and archaeology

Join us in Malta and Gozo to discover the islands' many exceptional archaeological sites, from the ancient and mysterious temples believed to be some of the world's oldest structures to the fortifications of the Knights of St John, which withstood unprecedented bombardment in the second world war. Led by award-winning journalist Juliet Rix, the six-day tour begins on 8 November and costs £1990.

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Podcast

Weekly

In the latest episode, the team discuss why the Amazon rainforest may have passed the tipping point that will flip it into a savannah. *New Scientist's* Sam Wong also gets them to taste-test a West African fruit called the miracle berry, and explains how it could help curb our sugar addiction. Plus, there are recordings of chimps drumming on tree roots in Uganda.

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Great Ġgantija Discover megalithic temples on the island of Gozo

ADRIAN SOLDATI/ANIMAL BEHAVIOUR

Beat that Listen to the musical drumming of chimps in Uganda

Video

Back of the net

What a goal! DeepMind's artificial intelligence has learned to play soccer. By imitating motion-capture video clips of humans playing the game, the AI learned how to control digital humanoids, taking them from flailing amateurs to proficient players. The team behind it is using the same approach to teach robots how to manoeuvre objects.

youtube.com/newscientist

Newsletter

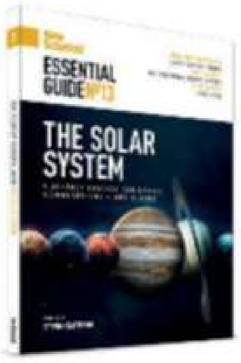
Lost in Space-Time

This month, we hear about a mind-blowingly enormous mathematical concept, a number called TREE(3), which is so big it can't even fit into the universe. Antonio Padilla, a physicist at the University of Nottingham in the UK and author of *Fantastic Numbers and Where to Find Them*, explains why.

newscientist.com/lost-in-space-time

Newsletter

> "After a year, you will have drawn more than a trillion, trillion, trillion, trillion trees"



Essential guide

How does the sun work? Why does the moon matter? Is there alien life? Knowledge of our solar system has reached new heights – but there is still much to discover about our nearest planets and the worlds beyond. Explore more in the latest *New Scientist Essential Guide.*

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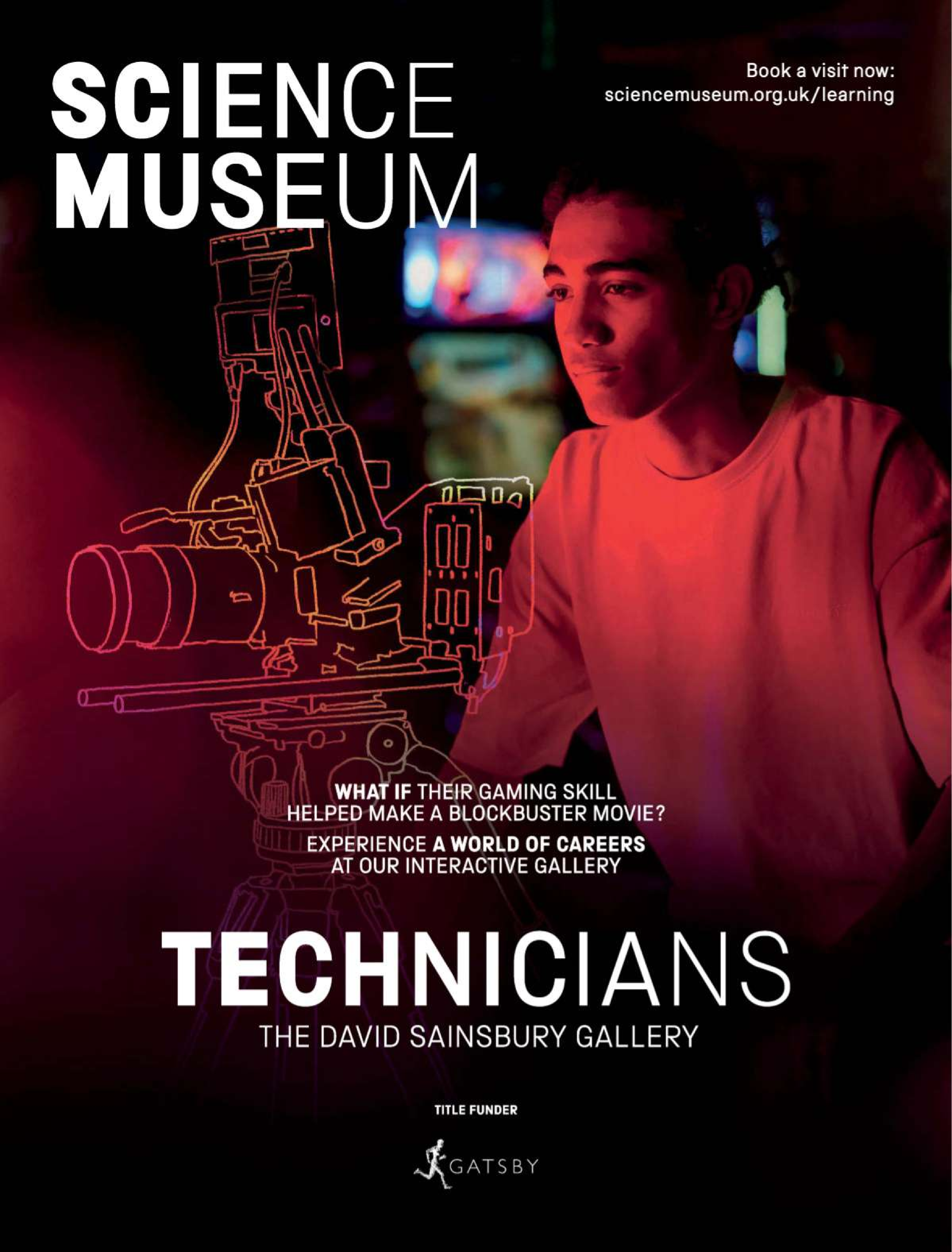

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Shoot for the moon

We should return to the moon not to escape Earth, but to learn to live better back home

ASTRONAUT Gene Cernan was the last person to walk on the moon, in 1972. "Apollo came before its time," he said. "President Kennedy reached far into the 21st century, grabbed a decade of time and slipped it neatly into the 1960s and 1970s."

Fifty years later, we have reached that decade of time. Many nations and private enterprises are plotting crewed missions to the moon. This time, it isn't merely a race to get there. The intention is to build a lasting presence, as we explore in a special feature starting on page 38.

You might reasonably ask why, when we have enough problems on Earth, are we spending billions to go back to the moon. If you are Jeff Bezos, you might answer that we need to relieve the ecological pressure on Earth by moving heavy industry off it and onto the moon. It is a nice idea, but it is a long-term prospect and won't, on its own, save our planet.

If you are NASA, or China's space organisations, you might think we need a presence on the moon for political reasons. "Control of space means control of the world," said former US president Lyndon Johnson, in shock, when the Soviet Union put Sputnik into orbit.

> "Once we are on the moon, we will learn to do things we should have done years ago on Earth"

Elon Musk has said that we need an independent human settlement as insurance for our species if there is a catastrophe on Earth – but that doesn't really wash when we are already facing catastrophe.

But we should go back to the moon for science, to explore, to create knowledge and to learn how to collaborate. The moon is a time capsule, a pristine record of how things were at the start of the solar system. From astronomy to studying the moon's water ice, science will be more easily done in person. Once we are there, we will learn to recycle efficiently and use renewable energy, things we should have done years ago on Earth. Once we are there, we will cooperate – as lunar settlements will need to be diverse and international. We have to ensure that this time, we create a presence on the moon that is a beacon of hope seen by everyone watching back home. ▮

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ANGELA WEISS/AFP VIA GETTY IMAGES

A researcher tests a sample for polio at Queens College, New York

Health

New York battles polio

A state of emergency has been declared to boost vaccination efforts after poliovirus was found in sewage samples, reports **Grace Wade**

NEW YORK has declared a state of emergency after tests on sewage samples showed that poliovirus is spreading in the community. Officials detected the virus – which was largely believed to be eradicated in the US – in five counties, including New York City.

"On polio, we simply cannot roll the dice," said Mary Bassett, New York's state health commissioner, in a press release on 9 September. "If you or your child are unvaccinated or not up to date with vaccinations, the risk of paralytic disease is real."

Polio is highly contagious. While more than 95 per cent of cases are asymptomatic or cause mild, flu-like symptoms, about 1 in 100 result in serious complications like meningitis or permanent paralysis, according to the US Centers for Disease Control and Prevention (CDC). Between 2 and 10 per cent of people with paralytic polio will die. Even those who fully recover can still develop paralysis up to 40 years later.

In July, an unvaccinated man from Rockland county, New York, became the first person in the US to test positive for paralytic polio in nearly a decade. Officials say he contracted the disease from someone inoculated with an oral polio vaccine, which contains a weakened version of the live poliovirus that can still replicate.

The US hasn't administered this vaccine since 2000, but it is still widely used elsewhere in the world because it is inexpensive and easy to use. On extremely rare occasions, the virus from the oral vaccine can revert to a form that causes illness and circulate in areas with low vaccination rates.

> "If you or your child are unvaccinated or not up to date, the risk of paralytic disease is real"

Following this case, state health officials in New York began analysing wastewater samples for polio, as people who are infected shed the virus in their stools. They identified polio in 57 samples taken from five counties between May and August. Genetic testing confirmed community spread and that all samples were types of polio that can cause paralysis.

No infected people have been identified besides the Rockland county man, but for every known case of paralytic polio, health officials estimate that hundreds of other cases are undetected.

While there is no cure, polio can be prevented through vaccination. Statewide, the vaccination rate is nearly 79 per cent, but counties where wastewater samples tested positive for polio have rates as low as 58.7 per cent.

The state of emergency authorises extra healthcare staff, such as midwives, paramedics and pharmacists, to administer polio vaccines. The measure also requires healthcare workers to send polio vaccination data to the state's department of health in order to track progress and direct immunisation efforts.

The goal is to vaccinate 90 per cent of all New York state residents. Officials also recommend that fully immunised adults who may come in contact with the virus, such as healthcare or sanitation workers, get a booster.

"We have the ability to keep people protected," says David Hirschwerk at North Shore University Hospital in New York. "The state of emergency declaration allows a sharper focus on the problem."

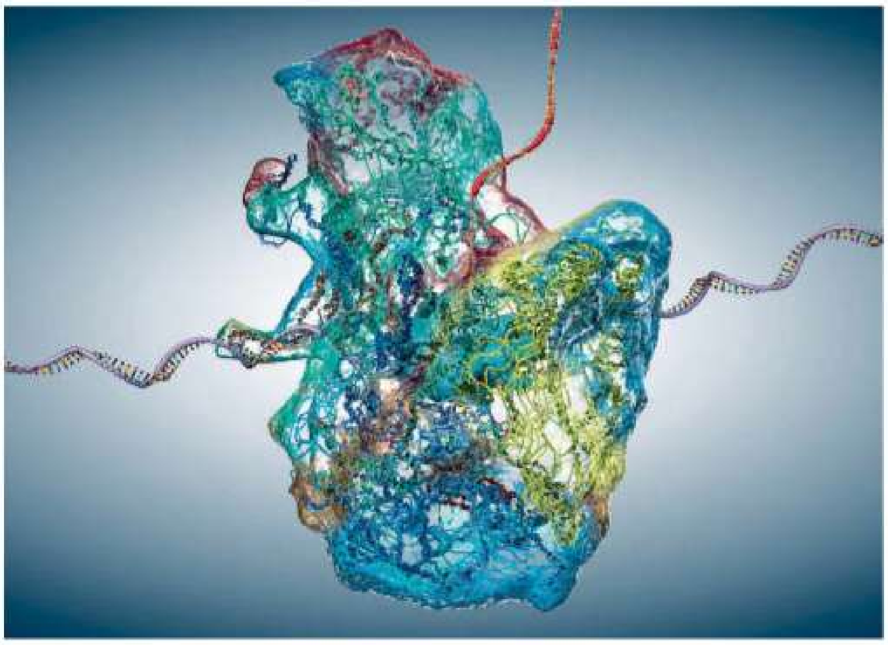
The US, UK and many other high-income nations use a polio vaccine containing inactivated poliovirus, which cannot replicate, and is more than 99 per cent effective at preventing infection, according to the CDC.

Poliovirus was also detected in sewage samples in London earlier this year. Health officials there have offered boosters to children aged 1 to 9. ▮

Molecular biology

Self-replicating ribosomes are a step towards artificial life

Carissa Wong



CHRISTOPH BURGSTEDT/ALAMY

Ribosomes build proteins by reading genetic instructions

TINY protein factories, or ribosomes, have been made to self-replicate outside a living cell for the first time. The achievement is a crucial step towards building self-replicating artificial cells from scratch and understanding how the first living things started reproducing themselves.

Ribosomes are where the genetic code gets translated into proteins – complex molecules that make up the machinery of living cells. In order for the earliest life to get going, many researchers think ribosomes must have been able to assemble and replicate before there were cells.

But ribosome self-replication is incredibly complex, involving around 200 types of molecules coming together in just the right way, so scientists have struggled to make this happen in the laboratory.

"Ribosomes are solely responsible for protein synthesis in all known forms of life. How ribosomes self-replicate themselves is a big question," says Wataru Aoki at Kyoto University in Japan.

Now, Aoki and his colleagues have finally established the conditions required for ribosomes to replicate themselves outside a cell – after seven years working to optimise the reaction mixture.

The researchers put DNA coding for ribosome components along with ribosomes derived from *E. coli* cells into a tube. To that, they added a tweaked version of the liquid, or cytoplasm, extracted from *E. coli* cells.

200

Types of molecules involved in ribosome self-replication

Guided by an artificial intelligence, the researchers established the precise molecular cocktail that would kick-start ribosome self-replication. The winning formula enabled ribosomes to produce new ones within 3 hours (bioRxiv, doi.org/gqsg5w).

"We suspected it was a false positive. However, no matter how many times we repeated the experiment and analysed it from other approaches, we found that the signal was indeed observed," says Aoki.

It is unclear whether the new generation of ribosomes then self-replicated or how many rounds of replication are possible. "Nascent ribosomes may self-replicate themselves to produce another set of ribosomes. However, there is currently no good way to separate signals [between these ribosome generations]," says Aoki, whose team is working to resolve this question.

Further work will also be needed to pinpoint all of the components within the *E. coli* cell extract that are critical for the reaction. Nevertheless, the achievement is a big step forward.

"Being able to construct a ribosome that makes a copy of itself, outside of a live cell, is a huge milestone resulting from large feats of engineering," says Kate Adamala at the University of Minnesota. "It's significant not only for making synthetic cells, but also for the studies of the origin of life."

"This is indeed exciting work," says Jan van Hest at Eindhoven University of Technology in the Netherlands. "Ribosomes are one of the most complex machines in our cells. Making them in the test tube solves one of the stumbling blocks to construct self-replicating artificial cells."

Learning how to create artificial cells could help researchers develop new research tools and therapies. Quoting the theoretical physicist Richard Feynman, Aoki says: "What I cannot create, I do not understand." ▮

Human evolution

One mutation may make us smarter than Neanderthals

Michael Le Page

MODERN humans have a mutation that boosts the growth of neurons in the neocortex, a brain region associated with higher intelligence. The mutation is absent in more ancient humans like Neanderthals.

"We can assume that it made us smarter," says Anneline Pinson at the Max Planck Institute of Molecular Cell Biology and Genetics in Dresden, Germany.

"I would say so," says her colleague Wieland Huttner. "But we cannot prove it."

The mutation results in a single amino acid change in a protein called TKTL1. Previous studies have shown that this mutation is present in almost all people today, but not in more ancient humans, such as Neanderthals and Denisovans, or in other primates.

The TKTL1 protein is known to be produced in the progenitor cells that give rise to the neocortex – the outer layer of the brain involved in conscious thought and language – suggesting that the mutation helped shape our brains.

To find out what difference the mutation makes, Pinson, Huttner and their colleagues added the modern human TKTL1 protein to the brains of mouse and ferret embryos. They also grew brain organoids from human cells, some of which were gene edited to produce the older version of TKTL1 (*Science*, doi.org/jbxw).

The mutation increased the number of neocortex progenitor cells, called basal radial glia, which resulted in more neurons. This would increase the size of the neocortex, or the density of neurons in it, or both, says Huttner.

Studies of skulls suggest that the brains of modern humans and Neanderthals were similar in size, but Neanderthals had more elongated brains. The researchers speculate that this difference in shape is due to the mutation. ▮

Astronomy

Massive satellite could outshine all the stars and planets in the night sky

Jonathan O'Callaghan

A LARGE satellite that launched to space last week could become brighter than any other object in the night sky except the moon, raising concerns about its impact on astronomy.

The BlueWalker 3 satellite, built by Texas-based firm AST SpaceMobile, launched on a SpaceX Falcon 9 rocket on 10 September. The satellite is designed to test the company's technology to beam a cellular connection, including 4G or 5G internet, directly from a satellite to mobile phones, enabling users to receive mobile coverage in remote locations.

Orbiting 500 kilometres above Earth, the 1500-kilogram satellite is set to deploy a huge antenna spanning 8 metres across, with a surface area of 64 square metres – about the size of a squash court. This large, flat surface will reflect a lot of sunlight, which could make the satellite extremely visible to observers on the ground.

For astronomers, it could create bright streaks across images from ground-based telescopes, potentially making them unusable for observing more distant objects.

> "I would really see this as an infringement on astronomers' rights to explore space"

"We are concerned," says John Barentine, an astronomer at Dark Sky Consulting in Tucson, Arizona. "It could be the brightest object in the night sky [other than the moon], potentially brighter than the planet Venus."

Barentine says there are also worries about the direct-to-mobile technology of the satellite, which involves a powerful radio beam connecting with a phone. That could disrupt radio astronomy, which requires very sensitive instruments to study the universe. "We're concerned about the amount of energy in that beam," he says. AST SpaceMobile didn't respond to a request for comment.

The firm is one of several companies developing new direct-to-mobile services. Starting from next year, AST SpaceMobile plans to launch more than 100 larger satellites called BlueBirds. These could be more than twice the size of BlueWalker 3, and could appear even brighter in the sky. "The brighter these objects get, the more damage they will do to images of the night sky," says Barentine.

Chris Johnson, a space law adviser at the Secure World Foundation in the US, says that while there are no restraints under international law on the size of satellites, the launch could highlight the limitations in existing regulations. "I would really see this as an infringement on astronomers' rights to explore space," he says.

The Federal Communications Commission (FCC) in the US has issued an experimental licence for BlueWalker 3, but a full licence for AST SpaceMobile's later satellites may depend on the performance and impact of BlueWalker 3. "The FCC appears willing to see how it goes and decide on a full licence later," says Tim Farrar, a satellite communications consultant in the UK. The FCC declined a request to comment. ■

Neuroscience

Quantum diamond used to measure neural activity

A BRAIN-recording device with a quantum diamond sensor has been used to measure neural activity in mouse brain tissue. The method could one day be useful for non-invasive brain scanning.

The most common way to study how neurons interact is to measure their electrical signal, typically by inserting tiny wires into a tissue sample. But this might alter neural activity, so a non-invasive method would be preferable.

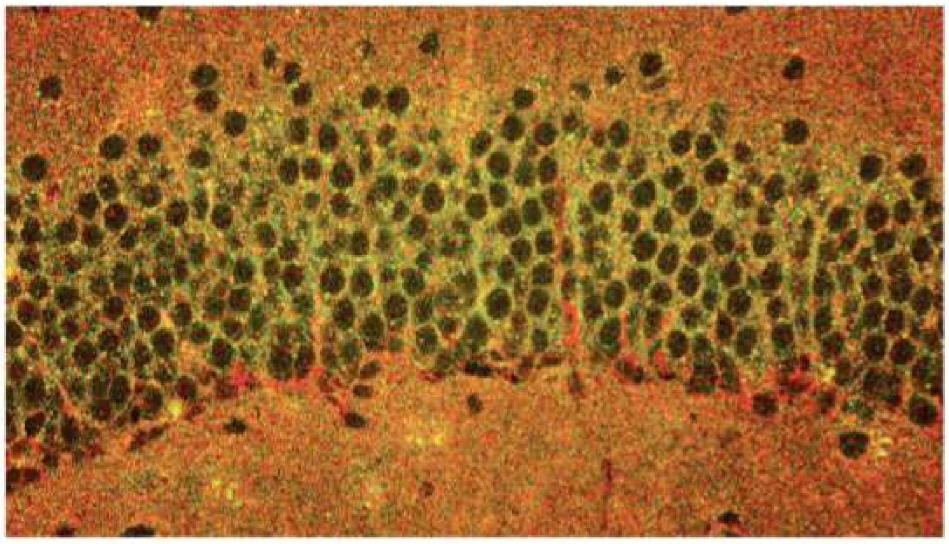
One possible technique is by using a modified diamond that shines more or less brightly depending on the brain-generated magnetic field passing through it due to a quantum mechanical quirk: certain defects in the diamond have their electron spin affected by external fields, which shows up as luminescence. This has been previously done with giant squid and worm tissue.

Now, Alexander Huck at the Technical University of Denmark near Copenhagen and his colleagues have created a quantum diamond sensor to measure the activity of mouse nerve cells. They tested it on nerve fibres in a slice of brain from a region known as the corpus callosum. By placing the scanner over the tissue sample, after 300 trials, the team recorded neural activity that largely agreed with data from inserted wires (arxiv.org/abs/2208.14068).

It can only detect the signal from groups of neurons rather than individual ones, but Huck says an improved sensor could help us observe what happens in brain samples at the microscopic scale.

The inability to see what is happening in single neurons means the method is unlikely to replace current brain-imaging techniques, says Tim Viney at the University of Oxford. However, developing the quantum diamond sensor could result in new techniques, he says. ■

Alex Wilkins



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New Scientist Live
A brief history of your brain
Emma Byrne at New Scientist Live
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Chemistry

Google AI can tell what something smells like from its molecular structure

Alex Wilkins

GOOGLE has used artificial intelligence to produce a map that relates smells to the structures of molecules. It is as reliable as a human in describing the aroma of a substance and the researchers behind the work say it is a step towards digitising odours.

The hope is that the AI model could one day be used to identify new scents for fragrances and flavours for food, or come up with chemicals to repel disease-carrying organisms.

Mapping how our perceptions of smell relate to the physical source of an odour is difficult. Unlike the colour sensors in the human eye, which detect just red, green and blue, there are more than 300 scent receptors, so there is a far greater diversity of scents that we can potentially detect.

Differences in people's capacity to smell, subjective opinions on what things smell like and a lack of any obvious "primary" scents, akin to what exists for colours, only complicate things further.

This makes digitising smells – encoding information so that any smell can be recreated from its digital signature, like the RGB digital scale for colours – an incredibly hard task.

JOHN HOWARD/GETTY IMAGES

What we smell is linked to the structure of chemicals in the air

Now, Joel Mainland at the University of Pennsylvania and his colleagues, including researchers at Google, have used a neural network to make a map that links a molecule's structure with its odour and to measure how close molecules are in terms of smell.

The researchers only designed the model to link existing odours and molecules, but it seems able to predict the odour of molecules that have never been smelled before, too. "The neural network seems to be learning some sort of representation of molecules that is more fundamental than what we expected," says Mainland.

The model was trained on two flavour and fragrance data sets for more than 5000 molecules. Mainland and his colleagues tested its abilities by getting it to describe how 320 different molecules would smell based on their structure and comparing this against smell-based descriptions from 15 people. The model performed as well as the average person (bioRxiv, doi.org/jb72).

Mainland's colleagues also applied the AI to a data set of chemicals that repel mosquitoes to make a map relating molecular structure to how repellent the insects find the scents.

This enabled the researchers to identify molecules that would be at least as repellent as leading anti-mosquito products and which could be tested in trials (bioRxiv, doi.org/jb73). This method could be used to find molecules to deter other disease-carrying organisms, as long as training data exists.

It is impressive work, says Barry Smith at the School of Advanced Study, University of London. "What the work does is skip neurobiology and try to connect the structure of molecules to the perception of odours directly." He says it helps us understand odours of single molecules, but that isn't the whole story. "Nearly all of the smells we are aware of – wine, coffee, soap, other people, the sea – are due to a mixture of several hundred volatile molecules," he says.

It may also be an issue that the model can't distinguish between enantiomers, mirror-image molecules with the same structure, but different smells, says Smith.

Mainland acknowledges this and says future work will focus on models that can identify enantiomers and more complex mixes of molecules. ▮

Space

Juno prepares for close encounter with icy moon Europa

NASA's Juno spacecraft is about to give scientists their closest look at Jupiter's frozen moon Europa in more than 22 years.

The mission will swoop to around 350 kilometres above Europa's surface on 29 September, returning detailed images as well as data about the moon's magnetic field and its icy crust.

The last time a spacecraft got similarly close to Europa was in January 2000 when NASA's Galileo orbiter swung by at a distance of 351 kilometres.

"We've already completed all the preparations. We're really excited. Everything is on target," says Scott Bolton, the Juno mission's principal investigator. "Our flyby is rather unique. The part of Europa that we're going to be able to see doesn't have particularly high-resolution data on it from Galileo, so this'll be the first time we've been able to see that [region] at very high resolution," he says.

All of Juno's scientific instruments will be capturing data during the rapid pass, says Bolton. Its main camera, JunoCam, will produce a handful of wide-field views while its navigation camera, known as the stellar reference unit, will be tasked with taking a single, very high-resolution picture of a small patch of Europa's nightside, lit only by the scattered light from Jupiter's cloud tops.

Researchers also hope to use the flyby to glean insights into Europa's ice shell using Juno's microwave radiometer. Bolton likens the instrument to a radar device, "except it's passive, so we're just looking at emissions coming out [from Europa] as opposed to sending a signal in and watching it bounce off", he says. The radiometer's data could give scientists clues about the depth of the shell and may reveal if there are fractured regions or areas of liquid within the frozen crust.

The team will even look for signs of the water vapour plumes that studies have suggested emanate from Europa, though Bolton stresses that these features "would have to be going off at the right time in a way that we can see them". ▮

350 km

Juno's distance from the surface of Europa at the closest part of its flyby

Will Gater

Animal research

Studies of mice and men go awry

Mice are more stressed when handled by male experimenters than female ones, and the sex of researchers can influence the results of mouse experiments, reports **Jonathan Moens**

LABORATORY mice tend to be more stressed when they can smell men, making them behave differently in experiments depending on whether they are handled by a man or a woman. The finding raises important questions about past research using mice, since animal studies generally don't control for an experimenter's sex.

Todd Gould at the University of Maryland began investigating this issue after his team couldn't replicate a simple lab result. The experiment involved a "forced swim test", in which researchers place mice in a tank of water and see how long they keep trying to swim for. When they stop swimming, the researchers take them out, unharmed.

Surprise result

In previous tests with male experimenters, mice tried to stay afloat for longer if they were given ketamine, an antidepressant. But when Polymnia Georgiou, a female researcher who was working in Gould's team, carried out the test, the mice gave up quickly regardless of whether they were given ketamine.

"The first feeling was of surprise," says Gould. He had read a study published in 2014 that showed mice were generally more stressed and less responsive to pain when handled by men than women. To see if this explained the surprise result, Gould and his colleagues designed a series of tests to explore whether the sex of the experimenter influenced how mice behaved.

Mice were exposed to T-shirts worn by male and female researchers, as well as cotton swabs rubbed across the experimenters' wrists or elbows, or behind the ears. They found that mice would avoid sniffing and engaging with scents from male researchers and were either impartial or showed a slight preference for those linked to female ones.

> "The sex of researchers is something that we've all been ignoring because no one thought it mattered"

The team also repeated the ketamine experiments to see whether the sex of the researcher affected the drug's apparent effectiveness as an antidepressant.

Paradoxically, when male experimenters administered ketamine injections, mice were more anxious but showed a stronger response to the treatment on various tests, including the forced swim test and a test that looked at their preference for sugary food.

Gould's team showed that being handled by male experimenters caused the release of hormones known as corticotropin-releasing factors, which activated a pathway critical for ketamine's efficacy (*Nature Neuroscience*, doi.org/gqqsz8).

Targeting that pathway in humans may be important for the antidepressant effect of ketamine in them too, says Gould, but more research is needed to investigate this. In the meantime, he says it is important for scientists working with animals to really consider whether the sex of the experimenter is influencing their results.

"What it suggests is that every experiment that's ever been done with male experimenters has happened with the mice in a different state than experiments that have been done with female experimenters," says Jeffrey Mogil at McGill University in Montreal, Canada, who was part of the team behind the 2014 study. "And so, yeah, you're going to get different results."

The problem could apply to any animal with an acute sense of smell, including rats, says Gould. If so, a large proportion of critical scientific research on subjects from Alzheimer's disease to cancer may be subject to this bias. Mogil goes so far as to say that this finding may, in part, explain why science is facing a replication crisis where attempts to repeat key experiments often produce different results.

Many sources of bias

The sex of experimenters may be just one of many biases that we should account for, says Gerlinde Metz at the University of Lethbridge in Canada, who wasn't involved in the research. Her team published a study in July showing that male and female rats showed different stress and behavioural responses to human experimenters.

The shipment, breeding and handling of animals and their diet could all have an effect too, she says. "Even seasons can induce different effects."

Metz says scientists should try to control for as many of these variables as possible. People could wear gowns, clean up cages well in advance of an experiment and allow mice to get used to the experimenter so that the effect of their presence diminishes, says Mogil. But it is near impossible to keep things totally controlled, says Metz, especially when dealing with a creature with such a sophisticated sense of smell.

As a minimum, researchers should be reporting the sex of experimenters in their studies so that they can later account for potential differences in results, says Mogil. "That's something that we've all been ignoring completely because no one thought it was even remotely possible that it could matter, but it does." ■

SHUTTERSTOCK/JAVIROZAS

Laboratory mice are affected by the humans who handle them

New Scientist Live
Hear Chris Jackson on climate change at New Scientist Live
newscientistlive.com

Environment

Climate tipping points loom closer

Runaway processes such as collapsing ice sheets and thawing permafrost are likely to be triggered if we breach even the 1.5°C temperature goal, reports **Adam Vaughan**

THE collapse of the West Antarctic ice sheet and the abrupt thawing of permafrost are among six tipping points in Earth's climate that are now likely to be reached if global warming can't be kept below 1.5°C, the goal set by the Paris Agreement in 2015.

In 2008, researchers identified nine tipping points in the planet's climate system, processes such as ice melt that would become irreversible and self-perpetuating and that could speed up climate change. Now, David Armstrong McKay at the University of Exeter, UK, and his colleagues have completed the first major assessment of those possible shifts and how much global warming it might take to trigger them.

While it was previously thought that most tipping points would occur when the global average temperature rose around 3°C above that in pre-industrial times, the new study found that some could occur at much lower temperatures.

The number of tipping points has also expanded to 16. Some new ones have been added – including changes in the Labrador Sea, part of the North Atlantic, which could cool Europe – while others have been dropped, such as loss of Arctic sea ice, as it is no longer seen as having a tipping point dynamic.

The world has already warmed by 1.1°C since the industrial revolution – a temperature increase with a low possibility of triggering some tipping points. However, between 1.5°C and 2°C, six of them become likely, including the collapse of the Greenland ice sheet and the die-off of coral reefs. A further four become possible, from abrupt loss of ice in the Barents Sea to the collapse of the vital Atlantic Ocean conveyor belt, a large system of currents that carries warmer, tropical water north, disruption of which could lead to more extreme heat and cold on both sides of the ocean.

"Where we're heading is something like 2.6°C – that's definitely going to hit lots of tipping points"

"This provides really strong scientific support for rapid cutting of emissions in line with the 1.5°C goal," says Armstrong McKay. "But the closer you get to 2°C, the more likely some of these tipping points get. Where we're heading at the moment is something like 2.6°C – that's definitely going to hit lots of tipping points."

Last year's Intergovernmental Panel on Climate Change (IPCC) report highlighted the risk of tipping points, but didn't outline the temperatures at which each might be triggered. Armstrong McKay and his colleagues trawled scientific literature and asked experts to provide estimates of how much warming might be required to set off the tipping points (*Science*, doi.org/gqr8kh).

The reason the temperature thresholds have come down since 2008 is an explosion of research. Better modelling has been key, particularly of ice sheets. Bubbles of air thousands of years old in ice cores and other palaeoclimate records have helped us learn how ice sheets responded in the past when the world was 1.5°C hotter. Recent years have also provided observations showing early signs of destabilisation of the Greenland ice sheet and weakening of the Atlantic conveyer belt.

"The science of climate change has advanced hugely in the intervening 14 years and [the study authors] now provide a reassessment based on the latest science. And it is not good news," says Mark Maslin at University College London.

The tipping points can now be expected much sooner than thought. The IPCC has said we could pass the 1.5°C mark in the 2030s. "It's all a lot closer than we were feeling like they were before," says Armstrong McKay.

A different planet

One crumb of comfort is that the most imminent tipping points, such as the collapse of the West Antarctic ice sheet – which some scientists believe has already begun – won't have a huge feedback effect that leads to runaway warming.

Nonetheless, Armstrong McKay says it is urgent that societies act to stop tipping points being reached, to prevent impacts such as huge sea level rise, which could result from losing Antarctic and Greenland ice sheets over millennia or centuries. "We'd be locking in future generations to an extremely different planet with 10 metres or more sea level rise. It would completely reshape the coasts of every continent," he says.

As his team notes, most of the systems assessed "contribute significantly to human welfare". Maslin says events like the abrupt thawing of permafrost, which could accelerate warming, would "be devastating for human society and should be avoided at all costs".

The research doesn't consider how some tipping points could exacerbate or offset others. ▮

ALEXIS ROSENFELD/GETTY IMAGES

Die-off of coral reefs could be triggered after 1.5°C of warming

Disasters

California set for big increase in extreme wildfires

James Dinneen

BY 2050, days with extreme wildfires in California could become 57 per cent more frequent, even in a warming scenario with low greenhouse gas emissions. With very high emissions, days with extreme fire could nearly triple by the end of the century.

Since 1972, the area burned by wildfires annually in California has increased fivefold. A disproportionate amount of that increase has been from extreme fires, those that grow by more than 4000 hectares in a single day. "Any fire that burns 10,000 acres is a very aggressive, dangerous fire to fight," says Jon Heggie, a battalion chief at the California Department of Forestry and Fire Protection.

Using data on nearly 18,000 so-called fire-days between 2003 and 2020 – which includes fires at various locations – Patrick Brown at the Breakthrough Institute, a think tank in California, and his colleagues trained machine-learning models to isolate the role of temperature from other factors that affect fire risk, like wind speed and precipitation. They then tested the models' predictions against a different set of historical data.

The researchers used the best-performing models to test how warmer temperatures and drier fuel affected the risk of extreme fires. Under a scenario with less than 2°C of warming by the end of the century, the frequency of extreme wildfire days increased 57 per cent by 2050 relative to a pre-industrial baseline, and held steady until 2100. Under a high-emissions scenario, extreme wildfire days rose by 81 per cent by 2050, and by 174 per cent by 2100 (EarthArXiv, doi.org/jb7r).

Michael Flannigan at Thompson Rivers University in Canada says these results might be conservative. "Things are progressing much more rapidly than we thought." ▮

Plants

Europe's drought will lead to a huge wave of tree deaths

Michael Le Page

SWEN PFÖRTNER/DPA/ALAMY

Dead spruce trees in Germany in 2019, following a drought

SEVERE heat and drought in Europe this summer will lead to a massive wave of tree deaths over the next two or three years even if there is enough rainfall to bring the dry conditions to an end, experts are warning.

"Not only next year, but also in the following two to three years, we will see a cascade of tree mortality," says Jan-Peter George at Tartu Observatory, which is in Estonia.

Numerous studies around the world are showing that the extreme heat and droughts caused by global warming are killing off ever more trees, from tropical rainforests to boreal forests in the far north. Last year, for instance, George's team reported that the drying out of soils in Europe is increasing tree death rates across the continent.

His study, like others, found that these deaths typically start to occur a year or more after a drought hits. In other words, many trees that at present appear to have survived the latest drought and the wildfires could still end up dying.

An earlier drought in Europe, in 2018, led to the biggest wave of tree deaths for perhaps 170 years, Cornelius Senf and Rupert Seidl at the Technical University of Munich, Germany, reported last year. "We thus expect that this year and next, tree mortality will be high," says Senf.

> "Trees weakened by droughts are much more vulnerable to pests and diseases"

It is too soon to tell whether even more trees will die this time, says Seidl. "What made the 2018 event so detrimental was that it in fact was a three-year drought in many places," he says. "For the 2022 drought, we'll have to see how the next months and years will play out."

A 2021 study of tree rings from living and preserved trees found that the series of droughts in Europe since 2015 is unprecedented in at least the past 2110 years. "There is no recovery time any more between droughts," says George.

There are several interlinked reasons why droughts can lead to trees dying a year or more later. They can slowly starve and the tissues that transport water can be permanently damaged. Trees weakened by droughts are also much more vulnerable to pests and diseases, such as bark beetles and fungi.

Time to adapt

Warmer conditions are also adding to the stress on trees in another way, by allowing pests, such as the horse chestnut leaf miner, to start attacking them earlier than usual and thus to do more damage. "A lot of insect pests appeared sooner this year," says Leigh Hunt at the Royal Horticultural Society in the UK.

All this is a worry as trees have a vital role, says Hunt. They not only help curb global warming by soaking up carbon, they can also help limit the effects of warming by cooling cities and reducing flooding, he says.

Those that die shouldn't simply be replaced with the same species, says Hunt. Now is the time to start adapting to the future by planting more resilient species, he says, ones that are able to cope with all kinds of weather extremes, not just droughts.

Europe is far from the only place where drought is killing trees. In the US, power companies are warning that drought-stressed trees could fall in high winds and take down power lines. Such an event is said to have caused a fire that destroyed 200 homes in New Mexico earlier this year. ▮

Analysis **Climate change**

Why have we seen so many heatwaves in 2022? As well as China having the worst heatwave in history, many other places have smashed records. **Michael Le Page** investigates

REN YONG/SOPA IMAGES/LIGHTROCKET VIA GETTY IMAGES

The Yangtze river in Wuhan, China, left dry by drought this year

THIS year, China has endured the worst heatwave ever recorded. Many other parts of the world have also seen extreme heat, with numerous records smashed and devastating consequences, including many deaths. We have long been warned that ever more extreme heatwaves will occur as the planet warms up, but some events exceeded predictions. What is going on?

This year began with heatwaves in the southern hemisphere. In January, Paraguay set a new national record maximum temperature of 45.6°C (114°F), for instance.

There were even heatwaves in Antarctica, relatively speaking. In March, the temperature on top of the ice sheet at a place called Dome C hit -10°C (14°F). That is a huge 38.5°C (69°F) above the average high temperature at that time of year.

"In terms of the temperature excess above normal, the Antarctic heatwave appears to have been the most extreme that humans have ever directly observed, anywhere," says Robert Rohde at the non-profit organisation Berkeley Earth.

Another major heat event occurred in India during March and April, and over summer in parts of the northern hemisphere there was more of the same. In Europe, the heat led to wildfires and exacerbated drought, affecting food production, energy generation and river transport.

In July, the UK recorded a temperature of more than 40°C (104°F) for the first time.

Meanwhile, China was seeing the worst recorded heatwave in history. It lasted more than two months, with hundreds of places repeatedly exceeding 40°C, worsening a bad drought. "There is nothing in world climatic history which is even minimally comparable to what's happening in China," weather historian Maximiliano Herrera told *New Scientist* in August before conditions eased later that month.

45.6°C

New national record maximum temperature set in Paraguay

Even in September, the heatwaves aren't over, with extreme temperatures across parts of North America, north Africa, Asia and Greenland at the time of writing.

There is no doubt that the main underlying reason for this extreme heat is climate change. When the planet is getting hotter, temperatures will exceed whatever is regarded locally as a heatwave level more often and for longer periods overall.

"'Unprecedented' is unfortunately a term we will have to use summer after summer as long as the warming of the planet continues," says Michael Mann at Pennsylvania State University. "We can expect worse heatwaves, droughts, wildfires and floods until human carbon emissions drop to zero."

However, there is more to this year's extreme heat than warming alone. While the average global temperature is increasing in line with climate model projections, some of the extremes this year, such as the UK passing 40°C, are happening sooner than expected. "Persistent weather extremes are increasing beyond what climate models have predicted, in substantial part because they are not fully capturing the jet stream dynamics," says Mann.

The jet streams are bands of strong winds high in the atmosphere that circle each pole. Their positions and strength affect the weather at the surface. The streams are powered by temperature difference between the equator and poles, so the rapid warming in the Arctic is having a major effect on the northern jet stream, especially in summer.

One of the results is that this jet stream is splitting into two over Europe and Asia more often, says Fei Luo at the Free University of Amsterdam in the Netherlands. Between the double jets, high pressure systems that bring dry and potentially hot conditions are more likely to form and persist. Last year, her team reported that this explains why heatwave trends are increasing especially rapidly in Europe.

The behaviour of the northern jet stream might also explain why we are seeing so many extremes. The jet stream can develop kinks known as Rossby waves. South of where the jet stream bends north, there will be high pressure, while north of southward loops, there will be low pressure and rain.

When the Rossby waves remain in the same place for weeks, this leads to extremes such as the Russian heatwaves and floods in Pakistan in 2010, says Luo. "This is why a lot of extreme events co-occur."

In 2019, it was reported that two patterns of jet stream Rossby waves of either five or seven waves in the northern hemisphere are particularly likely to occur in summer and can lead to simultaneous heatwaves. This year, Luo reported that while climate models do reproduce these wave patterns, they underestimate the resulting extremes at the surface.

This could partly explain why climate models are underestimating heat extremes. And unless we stop carbon dioxide emissions, even the unprecedented heat events of 2022 will be surpassed, with ever more severe consequences. "It's very scary, actually," says Luo. ▮

Exoplanets

Two potentially habitable super-Earth planets spotted orbiting red dwarf star

Alex Wilkins

A PAIR of rocky worlds slightly larger than Earth are orbiting in the habitable zone around a dim red dwarf star and one may be the second most Earth-like exoplanet discovered so far.

The planets are called LP 890-9b – which had been spotted before but we knew little about it – and LP 890-9c, also called SPECULOOS-2c. Both orbit a star called LP 890-9 or SPECULOOS 2.

Amaury Triaud at the University of Birmingham, UK, and his colleagues, who found SPECULOOS-2c, say both planets are in the habitable "Goldilocks zone" around the star, where conditions aren't too hot or too cold, so liquid water could exist on the surface, and potentially life.

To find planets in other solar systems, astronomers can look for a star's light dimming as a planet passes in front of it. This is hard when a star is as bright as the sun because the planets are comparatively dim, but easier if the host star is cooler and darker, which is the case with red dwarfs.

The SPECULOOS telescopes in Chile helped discover exoplanet SPECULOOS-2c

ESO/ P. HORÁLEK

In 2021, NASA's Transiting Exoplanet Survey Satellite (TESS), which scans the entire sky for exoplanets, released a list of newly discovered potential planets. One of these, TOI-4306.01, also called LP 890-9b, caught the attention of Triaud and his team, so they have followed up with ground-based telescopes.

As well as confirming TESS's finding, they discovered a second planet, SPECULOOS-2c. It has a radius 30 to 40 per cent larger than Earth's and takes just 8.4 days to orbit its star. It is also tidally locked, which means it has permanent day on one side and night on the other. Despite these differences, the researchers calculated it was squarely in the habitable zone and could have liquid water on its surface. It also appears to be the second most habitable planet discovered so far outside our solar system, after TRAPPIST-1e (*Astronomy & Astrophysics*, doi.org/jbv5).

"The system is the second best at the moment to study the climate of or find out the atmosphere"

Triaud was part of the team that announced the discovery of TRAPPIST-1e in 2016 in a haul of at least three potentially habitable Earth-sized planets orbiting a red dwarf star called TRAPPIST-1. In the following years, more TRAPPIST planets were identified, and TRAPPIST-1e appeared most likely to be an Earth-like ocean world.

SPECULOOS-2c doesn't seem far off it, according to the team's data.

"From my calculation, the system is the second best at the moment to study the climate of or find out the atmosphere with an instrument like the [James Webb Space Telescope (JWST)]," says Triaud.

The definition of a habitable zone changes depending on the properties of the star concerned. Observations of SPECULOOS-2c with JWST could help us understand what makes a planet habitable, says Beth Biller at the University of Edinburgh, UK. However, the planet's larger-than-Earth size and closer proximity to its host star, which might imply a higher level of powerful radiation, counts against its potential habitability, she says. ▮

Technology

Trick makes objects seem heavy or light in virtual reality

VIBRATING pads placed on people's arms can make the illusion of holding light or heavy objects in virtual reality more convincing by making us disregard some inputs from our senses.

Some VR systems create a perception of mass by slowing down the movement of a virtual object relative to how much our limbs move. For example, if a person picks up a heavy metal sphere, the system can cause a "lag" by only moving a fraction of the distance that their hand moves in reality, giving the impression of heaviness. If they pick up a virtual sphere made of light plastic, the system can allow it to move slightly faster than the user's arm moves in reality, giving the impression of lightness.

But if that trick is used too strongly, the illusion breaks, says Yutaro Hirao at the University of Tokyo. "At some point, the user starts to feel weird," he says. "The user notices that the physical portion and visual portion is different. And then the user starts to feel like 'oh, it's not my body any more'."

Hirao's solution is to trick the user's brain into relying more on the visual information they are receiving than the sensation of the position of their limbs, which comes from sensors called proprioceptors in our muscles, tendons and joints.

His team placed small vibrating motors above tendons in the arm to add noise to the signals from proprioceptors, making the signal less useful and causing the brain to lean more heavily on visual information – which in this case comes from the virtual world.

In an experiment involving 20 participants in virtual reality, the researchers simulated different weights by changing the difference between the movement of users' hands and the virtual objects they were handling.

They recorded the point at which the discrepancy became noticeable and found that adding tendon vibration made the illusion more persistent (arXiv, doi.org/jb7p). ▮

Matthew Sparkes

Wildlife

Pine marten in the city

The elusive mammal was recorded by a camera trap in London

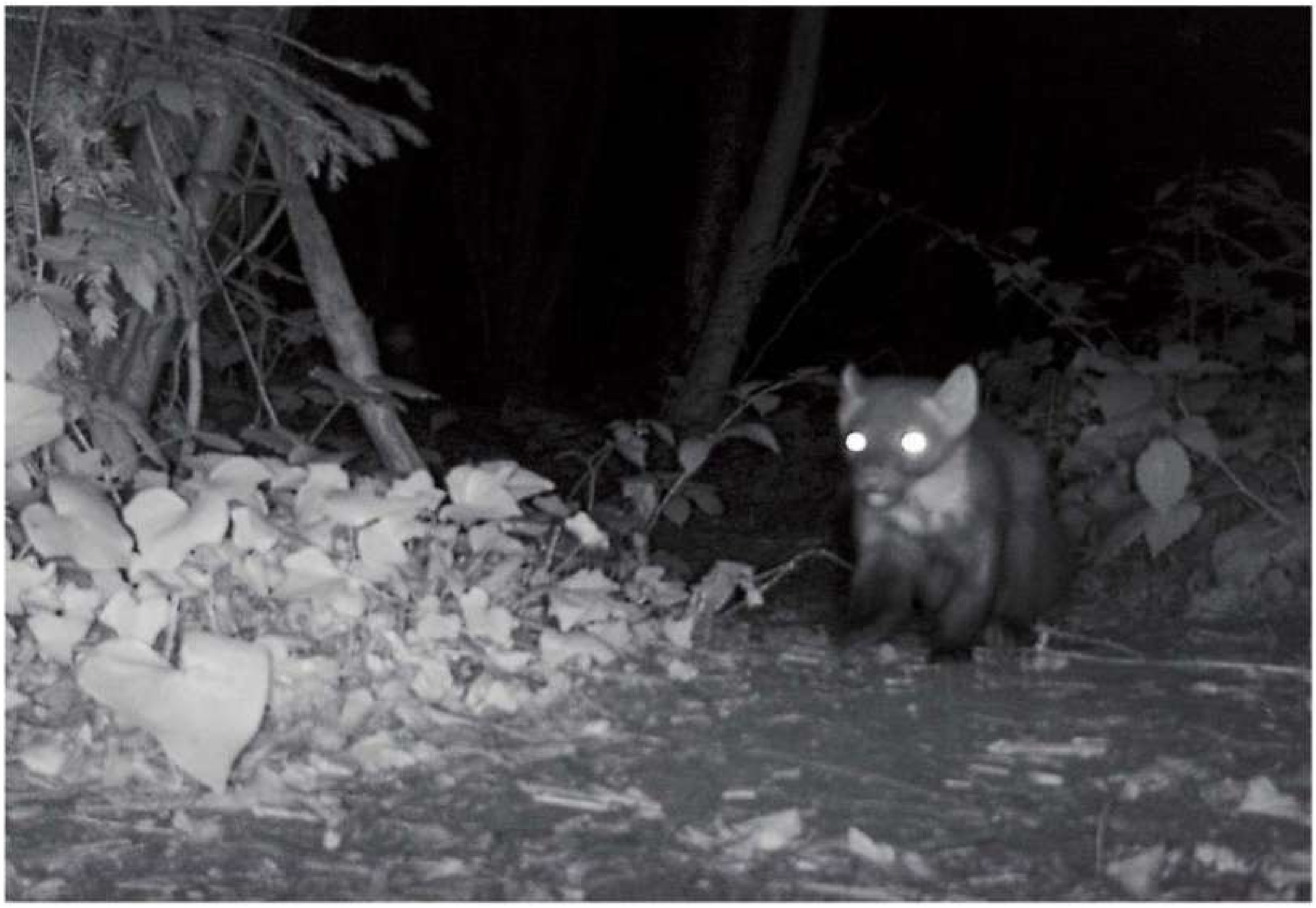
Adam Vaughan

A PINE marten (*Martes martes*) has been spotted in London for the first time since the 19th century, and just three years after the species was reintroduced to southern England.

While established in parts of Wales and Scotland and gradually recolonising northern England, the once-common species is still very rare in southern England. The animal was captured by a camera trap set up to monitor hedgehogs in the London borough of Kingston upon Thames.

Exactly how the individual came to be found so far from the closest known population, more than 100 kilometres away in the New Forest, remains unclear.

Kate Scott-Gatty at the Zoological Society of London says she normally has to sift through many photos of foxes and dogs to find hedgehogs. "To find a pine marten is pretty extraordinary."



LONDON HOGWATCH, ZSL

Health

Probiotic could treat rheumatoid arthritis

EATING a probiotic of harmless bacteria modified to make an immune-suppressing drug may relieve rheumatoid arthritis symptoms, according to work in rats, and it seems to be more effective than injections.

In rheumatoid arthritis, the immune system attacks the tissue that lines the joints, leading to joint pain, swelling and stiffness. As a result, people with severe forms of the condition are often treated using anti-inflammatory drugs that suppress the immune response. Some are delivered by tablet and others by injection.

Previously, a peptide called ShK-186, derived from sea anemone venom, has shown promise in treating conditions like arthritis.

However, like many other protein-based drugs used to treat arthritis, it must be delivered by repeated injections, which can reduce quality of life and increase the risk of infections.

Now, Christine Beeton at the Baylor College of Medicine in Texas and her colleagues have genetically engineered a bacterium (*Lactobacillus reuteri*) found in the gut and in yogurt so that it produces a modified version of ShK-186, called ShK-235.

"We thought, let's use one of those probiotics that's very well characterised and not dangerous to humans, and then modify it to produce our drug," says Beeton.

To test it, the team injected rats that had a version of rheumatoid arthritis with either ShK-235 or a control solution every other day for three weeks or fed them the ShK-235-producing probiotic daily instead.

Rats injected with ShK-235 had a 60 per cent reduction in swelling of their toes, wrists and ankles compared with the control group. Rats treated with the ShK-235-producing probiotic showed an even greater reduction, of 84 per cent (bioRxiv, doi.org/jbvs).

"The first time we tried it, we didn't quite believe it," says Beeton.

The team didn't see any harmful side effects, but before any clinical trials, more work is needed to see how the probiotic may influence other microorganisms in our bodies. "We also hope that probiotics could deliver existing injectable drugs too," says Beeton.

"If the treatment works in humans as it has in rats, they have a winning delivery system – but rats are different to humans, so it needs testing," says Paul Emery at the University of Leeds, UK.

Carissa Wong

New Scientist Live
How gut bacteria transplants can save lives
Blair Merrick at New Scientist Live
newscientistlive.com

Space

Laser on moon could propel light-sail craft across solar system

Alex Wilkins

A SWARM of tiny spacecraft propelled by a powerful laser could enable us to more rapidly explore space and map out the properties of the sun and distant planets.

One possible method for reaching other planets and stars is by using a light sail, a thin material that can be pushed through space by particles of light, or photons, at high speed. So far, experiments that use the sun's light to propel spacecraft have only been used near Earth.

Maria Pelizzo at the University of Padua in Italy and her colleagues have proposed using a powerful laser, placed either on Earth or the moon, to propel a group of small spacecraft at some 5 kilometres per second through our solar system and towards planets like Venus or Mars, or even the sun, so that they can map magnetic landscapes.

As well as providing new data about our solar system, these small craft could be a test bed for future interstellar travel, says Pelizzo. "It simplifies things, but still allows us to send many, many satellites and explore our solar system."

Pelizzo and her colleagues simulated the orbits and propulsion required for sending fleets of light sail-equipped CubeSats – existing satellites that weigh around 1 kilogram – out into space, calculating what sort of lasers might be required.

Most of the technology needed already exists, but for the system to function well, a powerful laser would probably need to be placed on the moon, which would take at least a decade, says Pelizzo (arxiv.org/abs/2208.10980).

Swarms of spacecraft or the use of light sails propelled by lasers aren't new ideas, says Ciara McGrath at the University of Manchester, UK, but using a swarm to map features of planetary atmospheres could be a useful addition to conventional space missions, she says. ▮

Archaeology

Child's foot successfully amputated 31,000 years ago

Clare Wilson

A STONE AGE child living 31,000 years ago in what is now Borneo seems to have had their foot and part of their leg carefully amputated and survived for several years afterwards.

This suggests that the hunter-gatherer community the person was part of had the medical skills to stop someone bleeding to death or dying from infection. These were both common hazards of amputation before modern medicine, says Maxime Aubert at Griffith University in Queensland, Australia.

10-14

Age of the child when the amputation happened

Before the latest finding, the earliest known case of a successful amputation – one that wasn't fatal – involved a 7000-year-old skeleton of an older male farmer, found in France, whose arm had been removed above the elbow.

It has been suggested that medical knowledge started advancing with the dawn of farming, about 12,000 years ago, which allowed larger, settled communities to hand down their skills. But the Borneo skeleton suggests that at least some earlier hunter-gatherers had sophisticated medical techniques, says Aubert.

The skeleton was discovered in 2020 during the excavation of a cave called Liang Tebo, which is accessible only by sea, in East Kalimantan in the Indonesian portion of Borneo.

The individual, named Tebo 1, was 19 or 20 years old when they died, judging from their bones. Their sex couldn't be determined because the skeleton has some features of both sexes and their DNA hasn't yet been sequenced.

Aubert and his colleagues were surprised to find that the person's left leg had been cut off above the foot, and the bones showed signs of healing, indicating that they survived for between six and nine years after the loss of their foot. This meant the person was between about 10 and 14 when it happened.

A deliberate amputation seems most likely because the two lower leg bones have a relatively clean cut, as if from a blade, rather than a crushing injury or a predator's bite, say the researchers. The remaining lower leg bones are thinner than normal and are fused together, perhaps because the person put weight on their stump (*Nature*, doi.org/gqr3c6).

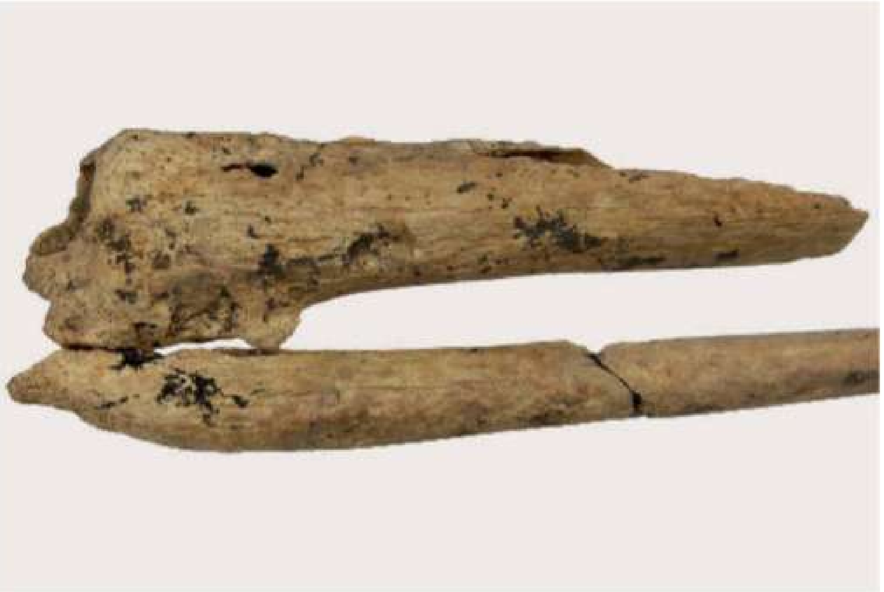
Advanced healthcare

The bones showed no signs of infection, which suggests that the wound had been regularly cleaned and disinfected, perhaps with antiseptic plant extracts, says Melandri Vlok at the University of Sydney, who was also part of the study. "You're looking at quite advanced forms of healthcare," she says.

When the individual died, it seems someone deliberately buried them, judging by the different kind of earth that was lying above the skeleton, as well as limestone rocks placed over the head and each arm. They had been laid on their back and buried with a ball of red ochre, used as paint at the time, and small flakes of quartz, sometimes used as tools.

In 2018, some of the nearby caves were found to have striking hunting scenes painted on their walls in ochre, thought to have been made about 40,000 years ago.

Eric Crubézy at the University of Toulouse in France says it wouldn't be impossible to survive an amputation without the help of other people – but the find is an interesting glimpse into life in this Stone Age group. "They must have had an understanding that it was necessary to remove the limb for survival," he says. ▮



TIM MALONEY

This tibia and fibula have fused together near where they were cut

Field notes IBM, New York

The world's largest quantum computer fridge

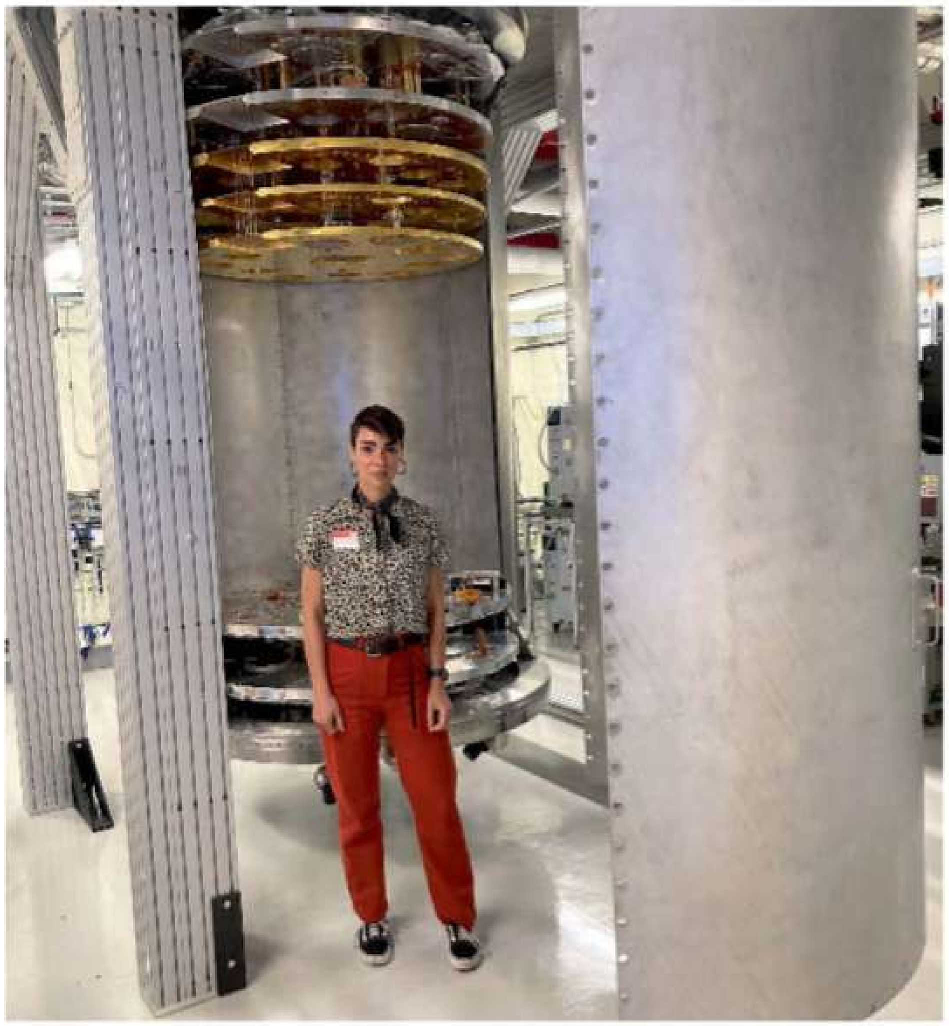
IBM has built a device that can become 100,000 times colder than outer space. **Karmela Padavic-Callaghan** takes a look inside

IN THE Hudson Valley, an hour's train trip away from New York City, I am struggling to move a big, curved piece of metal. It is at the front of a large, cylindrical machine at least twice my size. IBM physicist Pat Gumann lends a helping hand and, together, we get it done. Closing the door of the world's largest quantum computer fridge is no joke.

Quantum computing relies on keeping things cold. The quantum properties that make the computers work disappear at temperatures as cold as just a few degrees kelvin (around -271°C). The best fridges currently available can handle quantum computers with hundreds of quantum bits, or qubits – the basic quantum unit of memory. But to really start excelling over classical computers, quantum computers will need thousands of qubits. IBM wants to build one with 4000 qubits by 2025, which would be about 300 times more than its current biggest quantum computer. And for that, the team is going to need the massive fridge in front of me.

Gumann led the researchers who built it. It is fondly nicknamed Goldeneye after the James Bond film and its interior can reach 25 millikelvin, about 100,000 times colder than outer space. The fridge is a cylinder 2 metres in diameter and about 4 metres tall, but much of that is taken up with the tech to keep it cool. I suspect that I could just about fit in the compartment for quantum computers, but I don't dare for fear that the thin wires and gaskets won't survive the interaction with my sneakers.

It took the team three years to build Goldeneye. Rather than requiring a huge conceptual leap, it was more about rethinking every small detail to take cooling technology to the extreme.



IBM's new fridge. *New Scientist* reporter Karmela Padavic-Callaghan for scale

Take the metal parts that move heat away from the centre of the fridge. They had to be made with extremely pure copper so they would be very efficient conductors of heat. But sufficiently good copper was only available in bricks from Germany. The team had to import it and find a specialist forge that could turn it into the right shapes. The fridge was then a result of taking similar care with every component.

A household fridge cools by circulating a liquid refrigerant that turns from a liquid into a gas. This process of evaporation takes heat, resulting in an overall drop in temperature. Goldeneye does something similar, but rather than relying on the phase transition from a liquid to a gas, it transforms liquid helium into a series of exotic quantum states of matter, including a superfluid. This produces an even more powerful cooling effect.

To get a better look at where the action happens, I stand on a step ladder and peer from the top down into Goldeneye's belly. There are five large, circular, evenly spaced metal plates – some of which are made from the German copper bricks – connected vertically by thin metal wires that the helium runs through. Each plate contains cooling components that take away increasingly more heat so that the one closest to the centre of the fridge is 1000 times cooler than the one at its top. At the bottom, another stack of metal plates will be an exact mirror.

Most commercially available fridges used for quantum computers open vertically, but had the team just scaled up that design, the fridge would have ended up tall enough to break the lab's ceiling, says Gumann. The team put a lot of thought into avoiding this and came up with the door design that gave me trouble.

"Some people don't really appreciate fridge building because they think it's like plumbing, but you actually have to design it extremely carefully to get to low temperatures," says Mikko Möttönen at Aalto University in Finland. He says that compared with the biggest fridges he has been able to buy for his own lab, Goldeneye has about 10 times more space for chilling quantum processors. "Fridges are to quantum-computer engineers what space shuttles are to astronauts," he says. "The larger, the further they can take you."

4 metres

The height of the world's largest fridge for quantum computers

Back in May, after Goldeneye took about two weeks to reach its lowest temperature, the team placed a 10-qubit chip inside of it and performed diagnostic measurements to determine how well qubits would perform a calculation. These diagnostics showed that the chip worked perfectly well inside the fridge.

Though Goldeneye will move to IBM's new Quantum Data Center in Poughkeepsie, also in New York, later this year, the company's quantum computers don't yet require that much space. Goldeneye is aspirational, says Gumann. The many lessons the team learned by building it will be invaluable for improving smaller fridges too, he says. ▮

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Engineering

Crow-beak tweezers easily pick up beads

TWEEZERS based on a crow's beak can work better at picking up objects than the types people have used for thousands of years.

Takahito Murakami at the University of Tsukuba, Japan, and his colleagues 3D-printed a pair of tweezers that mimicked the shape of the beak of the New Caledonian crow – an intelligent species known to use simple tools.

The team asked people to transfer glass beads with diameters of 3, 5, 8 and 14 millimetres from one dish to another with their fingers, traditional tweezers and the new tweezers. The crow-beak tweezers were faster to use than traditional tweezers with 8 and 14-mm beads. Most users reported that the bird-inspired tweezers were easy to use (arxiv.org/abs/2208.12961). **Matthew Sparkes**

Space

Weird planets may be stolen from stars

PLANETARY theft could explain why a strange trio of planets are in orbits that they shouldn't be in.

In late 2021 and early 2022, three huge planets were found with wide orbits around B-type stars, very hot stars more than three times as massive as the sun. "I wouldn't expect planets to be able to form around these stars, let alone such huge ones," says Richard Parker at the University of Sheffield, UK.

He and Emma Daffern-Powell, also at the University of Sheffield, ran simulations of star-forming regions similar to the areas where these worlds were spotted. Based on these, they believe that two of the three planets were probably free-floating worlds that were captured, and the third was probably stolen from another star (*Monthly Notices of the Royal Astronomical Society: Letters*, doi.org/gqr2kn). **Leah Crane**

BARBARA KLUMP (CC BY-SA)

Animal behaviour

The best way to stop a bin-raiding cockatoo

RESIDENTS of Sydney, Australia, are caught in a battle of wits with cockatoos, as they try to stop the crafty birds raiding their rubbish bins for food.

As fast as they come up with new ways to stop the sulphur-crested cockatoos (*Cacatua galerita*, pictured), the birds are working out ways to defeat them. It is a classic example of an arms race in cultural evolution, says Barbara Klump at the Max Planck Institute of Animal Behavior in Radolfzell, Germany.

The lids are heavy, but a few birds found they could pry them open at the front, grip the lid in their beak while walking around the rim towards the hinge, then flip the lid. The trick was seen in only three suburbs of Sydney in 2018, but by 2019 it had spread to 44 suburbs as cockatoos learned the trick by copying each other.

The researchers have now observed the protection strategies being used by people on 3283 bins in four suburbs where bin-raiding by cockatoos had been reported, and gathered responses from 1134 residents in an online survey.

Some people started putting items like bricks on top of their bin lids, but some of the hungry birds figured out they could nudge the bricks off with their heads.

A more sophisticated tactic – which hasn't yet been defeated – is to wedge a stick or a pair of trainers between the hinges and the bin to stop the lid from flipping over.

The researchers found that protection tactics tended to cluster among neighbouring houses, leading them to conclude that people are copying each other's tactics just like the birds do (*Current Biology*, DOI: 10.1016/j.cub.2022.08.008). **Clare Wilson**

Really brief

TUUL AND BRUNO MORANDI/ALAMY

Device produces hydrogen from air

Hydrogen has been produced from water vapour in the air using a prototype device that can work in humidity as low as 4 per cent. The technology could make solar-powered hydrogen production viable even in deserts (*Nature Communications*, doi.org/gqr2zb).

Meal timing doesn't affect weight loss

For people trying to lose weight, the timing of the largest meal of the day may not matter. A study of 30 people found no difference in weight loss between those who ate more calories at breakfast and those who ate more at dinner, though a big breakfast did make them feel more full (*Cell Metabolism*, doi.org/gqsc4d).

Atomic clocks quantum entangled

Two atomic clocks have been connected using quantum entanglement, a property that intrinsically links them so that changes in one will instantaneously affect the other. The connection could be used to make more accurate measurements of dark matter and gravity (*Nature*, doi.org/jbvv).

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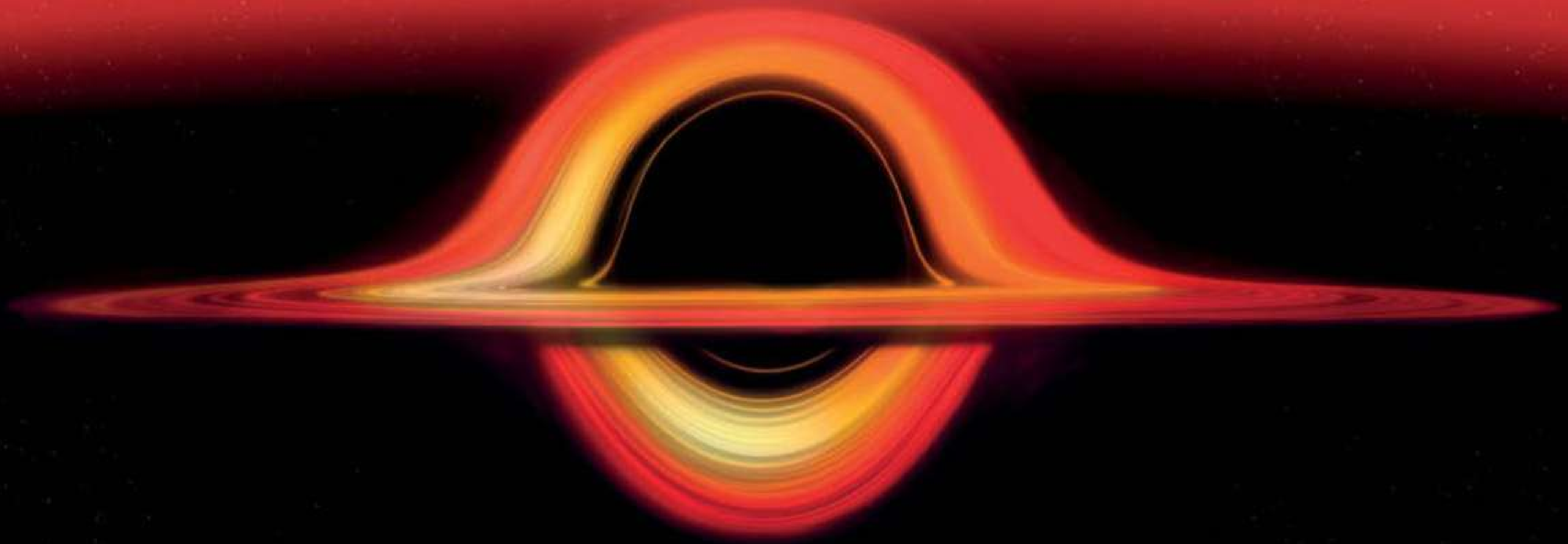

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Views

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Annalee Newitz on the corporate side of social media **p26**

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Photos and artwork capture the spirit of the ocean **p28**

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Will accessible HRT ever be more than a pipe dream? **p30**

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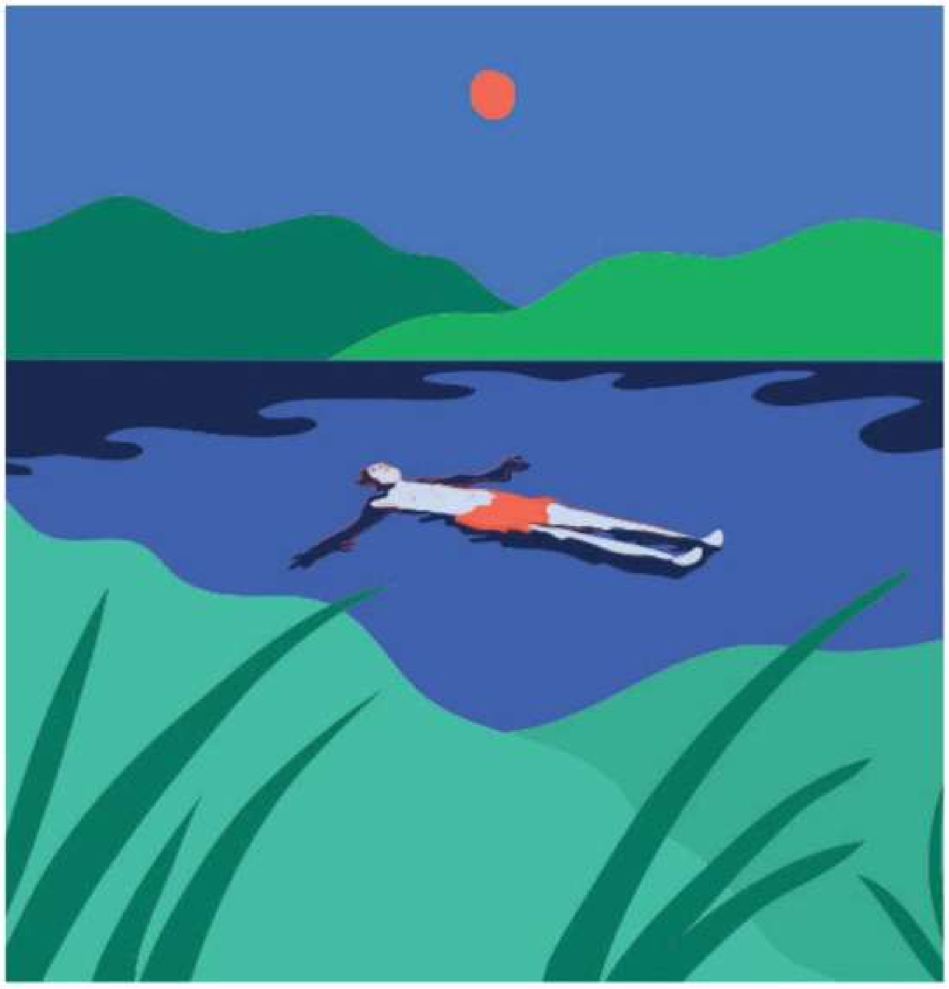
An account of the rise of YouTube explores its wider impact **p32**

Culture
Big History takes the wheel in a new guide to the future **p34**

Comment

Come on in, the water's cold

Outdoor swimming helps reduce inflammation, the cause of many health issues. It should be a public health measure, says **Mark Harper**



MICHELLE D'URBANO

THE popularity of outdoor swimming has been growing at such a rate, I am starting to worry I will run out of cold-water-naive participants for my studies on its health benefits. Perhaps there won't be a need to carry out further studies because everyone will be doing it anyway. But, in the meantime, there is good reason to consider why the provision of outdoor swimming should be a public health measure.

There is a strong physiological basis underpinning the many positive health effects of outdoor swimming. These benefits largely come from a reduction in excess inflammation through repeated immersion in cold water. The cold water affects inflammation in two ways: first, baseline and peak levels of inflammation are both lowered by the repeated exposure; second, putting your face in cold water directly stimulates the vagus nerve, and thereby the parasympathetic nervous system, which results in a further, short-term reduction in levels of inflammation.

Many of Western society's health challenges are linked to abnormally high levels of inflammation, including heart disease, high blood pressure, type 2 diabetes, arthritis, fibromyalgia and chronic pain. What's more, a significant proportion of cases of depression are associated with inflammation. A simple intervention that reduces inflammation could, therefore, be an effective public health measure.

The potential of cold-water bathing is supported by the results of our survey of 722 people "self-medicating" with the activity. As we had hypothesised, most people with inflammatory conditions found it helped their symptoms. Given the inflammatory aspect of both covid-19 and long covid, there is good reason to think that cold water could also help with these healthcare issues.

Most respondents were using cold-water bathing for their mental health. So, we enrolled 59 people with anxiety and depression into an eight-week sea-swimming course. Not only did we see an improvement in their symptoms during the course, but more than 80 per cent were still engaging in the activity and finding benefit from it three months later. Self-sustaining interventions, as this seems to be, are ideal public health measures.

Even if you don't have access to open water, one study showed that office workers who had cold showers took fewer sick days than colleagues who didn't.

The UK is particularly amenable to the widespread adoption of outdoor swimming because the water temperature needed to feel positive health effects is under 20°C – generally, the maximum found in our outdoor waters.

The main issue is safe access. With sewage alerts for English and Welsh beaches this summer, water quality needs to be addressed urgently. Then, legislation could be used to open up access and absolve land owners from liability. After that, organisations like the National Trust might be inclined to put in measures such as ladders and let people use their facilities.

People also need to become safe and confident swimmers through courses such as those run by Chill UK, which began with our clinical trial and is now rolling out around the country, or groups like Mental Health Swims. Swimmers also need to be aware of how to reduce their risk of cold water shock.

Happily, the potential benefits of cold-water swimming as a public health measure have been recognised by Fulton MacGregor, a member of Scottish parliament. As a result, we ran a roundtable at the Scottish parliament on 13 September. This will be followed by an in-person event in March 2023, bringing experts together to turn this into a reality.

In the meantime, the water is still relatively warm, so why not try an outdoor dip? Then you will be hooked when colder weather comes along. ■

Mark Harper is an anaesthetist, researcher and author of *Chill: The cold water swim cure*. @wildswimdoctor

This changes everything

Stop calling it social media It was meant to let us chat freely in a digital public square, but the firms running social media are just as corporate as old media, says **Annalee Newitz**

Annalee Newitz is a science journalist and author. Their latest novel is *The Future of Another Timeline* and they co-host the Hugo-winning podcast *Our Opinions Are Correct*. You can follow them @annaleen and their website is **techsploitation.com**

Annalee's week

What I'm reading
Naseem Jamnia's The Bruising of Qilwa, *an incredible tale of magic and epidemiology in a teetering democracy dealing with an immigration crisis*

What I'm watching
OK, yes, I will admit I am watching The Rings of Power *and it is really quite fun*

What I'm working on
Finishing up a book project I have been writing for a while

This column appears monthly. Up next week: Penny Sarchet

ANOTHER month, another algorithm change on a social media platform that has everybody peeved online.

This time it is Instagram, the photo-sharing service owned by Facebook. Instead of showing us the cat photos and wedding pictures we want, the app is clogging up our friend feeds with tons of "reels": autoplaying mini-movies. The problem? Nobody asked for this. The reels aren't from friends or people you follow. They are just random videos mucking up your feed and making it harder to find the pictures you want to see. As many Instagram fans pointed out, it is a pathetic attempt to compete with video-sharing platform TikTok.

The even bigger problem? Instagram's algorithm no longer favours photos, and that affects a lot of small business owners. If you are a maker who relies on Instagram to alert fans to your latest goods for sale, now you have to make a movie instead of posting an image. And it isn't just the little guys who are upset. Even Kim Kardashian and Kylie Jenner – two of the app's biggest influencers – promoted a petition asking Instagram to go back to "an algorithm that favors photos".

The platform's head, Adam Mosseri, responded to the uproar in a reel (of course) where he explained that video is getting more and more engagement on Instagram, so it won't be going away. He has since admitted Instagram might have "gone too far with video", but he has made no promises to change the current algorithm. This is yet another signal that Instagram is no longer "social media", a communication platform driven by its users – if it ever was. It is clear that users don't get their voice heard freely or decide what they see. Everything we do there is constrained by a group of executives who hand down content to their audiences.

For too long, so-called social media companies have perpetuated a myth that they are levelling the playing field of communication technology. Companies like Facebook rejected the top-down media model, where Hollywood studios shovelled crummy movies into our brains and we couldn't talk back. As social media participants, however, we were supposed to romp freely in a digital public square where everyone could speak and be heard. Now it is becoming obvious that social media companies are just as top-down as the old media ones. Nearly all of the media we consume online in the West is produced, hosted or distributed by just five firms: Google, Facebook, Amazon, TikTok and Twitter.

> "These companies perpetuated a myth of levelling the playing field of communication technology"

It is time we start calling it corporate media, dropping that "social" bit. Especially because it has become so resoundingly plain to many of us that none of the big five is interested in what their audiences want or in making their products genuinely social – unless it helps their bottom line by providing free content or positive ratings for their products.

Case in point: Amazon, hit by bad fan reviews of its very costly series *Lord of the Rings: The Rings of Power*, "paused" audience critiques and ratings of the show on its streaming site. Reps for the company explained the drama was getting "review bombed" – attacked by users with an agenda and bots giving one-star ratings. Amazon said this was driven by fans angry that the show featured Black actors as elves and dwarves; they were also upset that the female elf Galadriel fights with a sword as well as magic. So Amazon simply excised the "social" part of its media offering to bring audiences its series without any audience reviews on its site.

Amazon didn't seem so generous when it came to protecting its users, however. In 2019, several people on its social book review platform, Goodreads, noticed queer authors were getting review-bombed with one-star ratings that lowered their rankings on both Goodreads and Amazon. Often, these authors were getting the one-star reviews months before their books were even available as galleys.

When users sent abuse reports about this to Goodreads, support staff responded: "We do not dictate on what basis Goodreads members form their personal opinions about a book, so we have no rules about reading the full text of a book before rating and reviewing it." (Goodreads hasn't changed its policy since, and news site Book Riot reports that review bombing has become even more popular in the US this year.) It appears review bombing is fine, as long as it isn't directed at an Amazon product.

This is exactly how commercial media has always worked. By and large, executives and other gatekeepers choose a few offerings and use their power to push that content to everyone. Social media isn't for sharing ideas in some idealised public square. It is for companies to find new ways of monetising their content without taking responsibility for audiences who make that content valuable. That isn't social – just corporate. ■

Welcome to our Signal Boost project – a page for charitable organisations to get their message out to a global audience, free of charge. Today, a message from **Brain Research UK**

Funding research into devastating neurological conditions

WHO ARE WE?

Brain Research UK is the leading dedicated funder of neurological research in the UK. We fund the best science to achieve the greatest impact for people affected by neurological conditions, to help them live better, longer. Every year we receive more and more funding applications from promising young researchers and research institutes across the UK.

THE IMPACT MADE IN THE LAST 50 YEARS

In the years since we were founded in 1971, we have achieved so much. We transformed our researchers' ability to study the brain through technological advances including improved neuroimaging facilities and state of the art scanners. We have invested over £50 million into neurological conditions to enable the best research. Our researchers have made incredible breakthroughs: they have revealed genes and mechanisms underlying the early stages of brain tumour development which have led to new treatment possibilities; and identified protein clumping in motor neurones as a key feature of Motor Neurone Disease (MND) leading to the development of a new drug which has been shown to slow down functional decline in clinical trials.

THE CHALLENGE WE FACE

One of the biggest challenges we face is that despite 1 in 6 of us having a neurological condition, research into the brain remains woefully under-funded. Brain tumours, for example, kill more people under 40 than any other cancer and more children in the UK than any other disease. Yet, brain tumour research attracts only 1% of the national spend on cancer research.

Tragically, this under-investment translates into low survival rates. When diagnosed with glioblastoma – the most common primary brain cancer – a patient will learn that there is no effective treatment for their condition and that most people with glioblastoma die within a year of diagnosis. This is in stark contrast to other cancers, where higher investment in recent decades has delivered new treatments which are dramatically improving survival.

Want to help?

There are many ways you could help us, from raising awareness of the prevalence of neurological conditions to participating in or organising fundraising events. We don't receive any government funding and rely solely on the generosity of our supporters. Please visit our website brainresearchuk.org.uk to find out more about our work and how you can support us.

Do you need your signal boosted?

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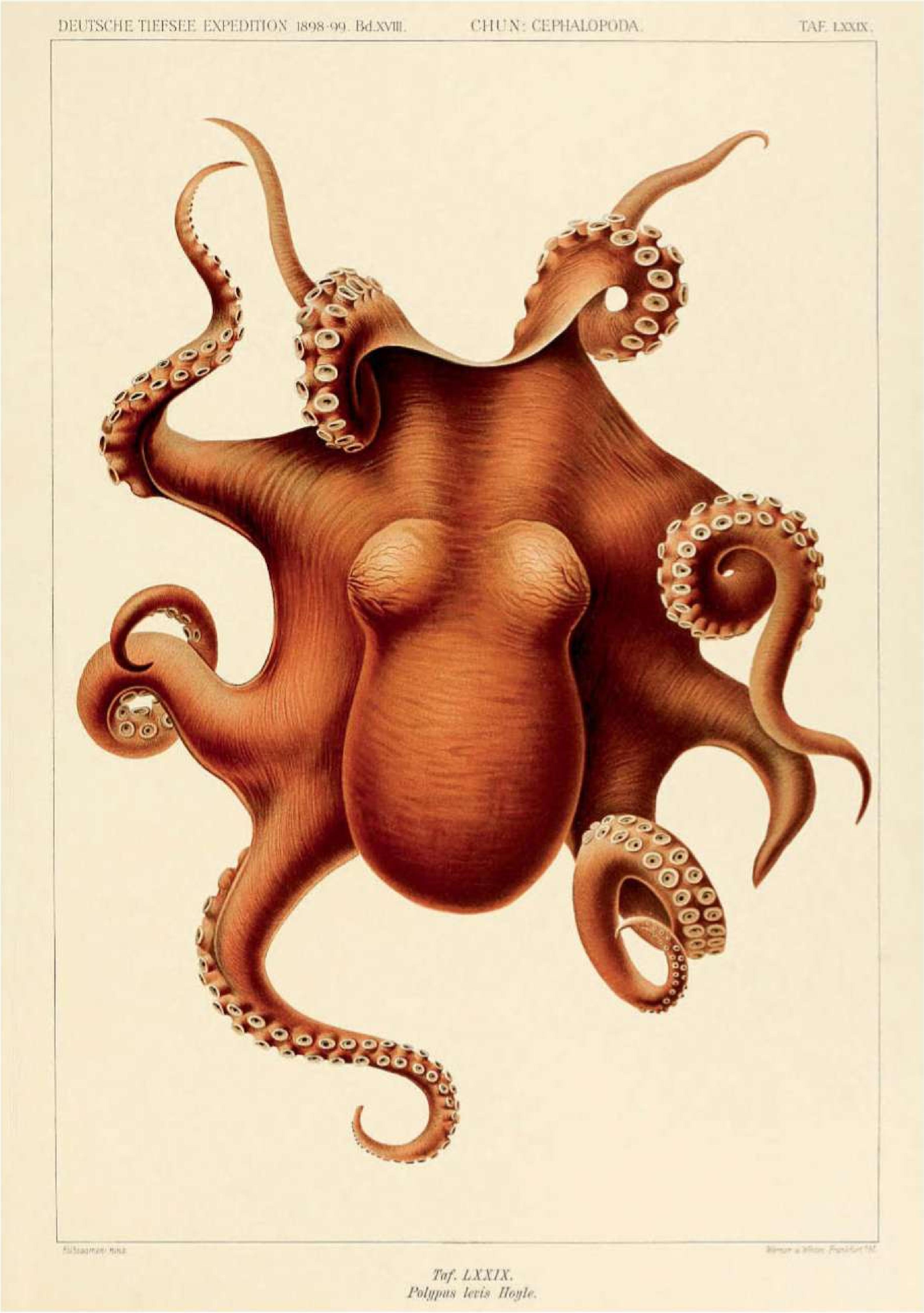
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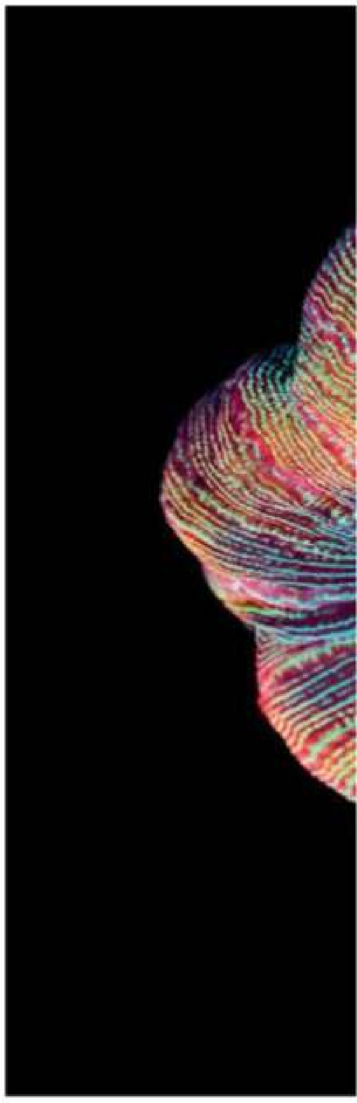

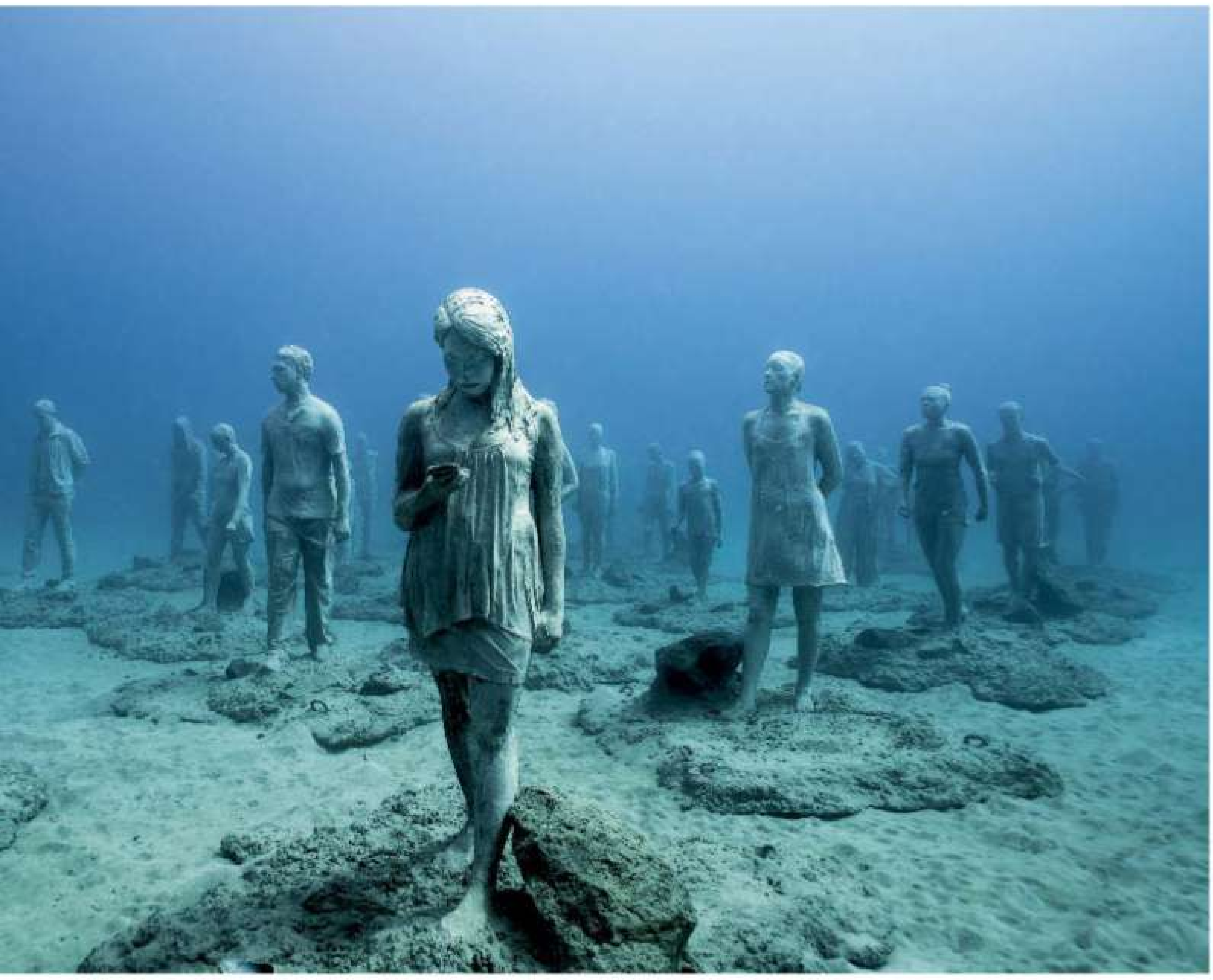

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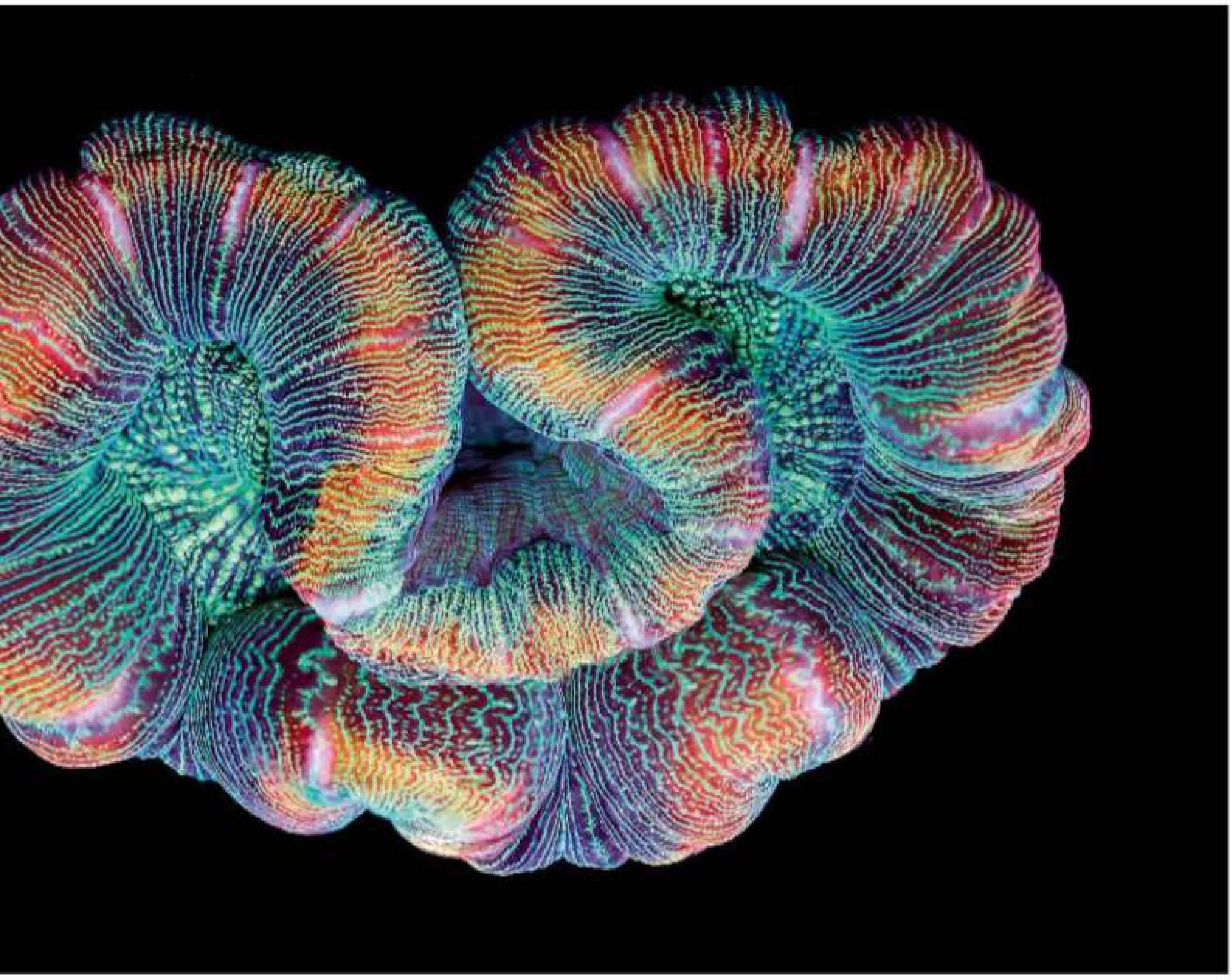

NNTONIO ROD

Art of the ocean

Book publisher **Phaidon Editions**

A WOMAN is immortalised, gazing at her phone, part of an anonymous crowd of sculptures by British artist Jason deCaires Taylor. But this is no ordinary setting: deCaires Taylor's pH-neutral marine cement figures (top right) are 14 metres underwater off the coast of Lanzarote, Spain, and will eventually be reclaimed by the sea. The work's name, *Rubicon*, draws from the idea the crowd, and the world, are heading towards a point of no return as temperatures rise.

The image of *Rubicon* is taken from a new book, *Ocean: Exploring the marine world*, which details how our oceans have been a "symbol of infinity, beauty, solitude, isolation, danger, happiness, weightlessness and longing" in art through the centuries. Featuring more than 300 images ranging from Roman mosaics to nautical cartography, *Ocean* also highlights how climate change has affected the seas.

NNtonio Rod (Antonio Rodríguez Canto) took 25,000 photos over the course of a year to make the award-winning time-lapse film *Coral Colors* (2016), from which the striking still *Trachyphyllia* (bottom right), featured in the book, is taken. Rod wanted his film to raise awareness of corals as they become more vulnerable to climate change-related bleaching.

Ocean also features marine biologist Carl Chun's stunning illustration (left) of an octopus (*Muusoctopus*, formerly *Polypus levis),* drawn from a specimen collected near the Kerguelen Islands in the south of the Indian Ocean during the 19th century. The illustration is included in *Die Cephalopoden*, Chun's seminal 1910 work on cephalopod molluscs.

Alison Flood

Editor's pick

I fear new HRT regime will prove to be a pipe dream

3 September, p 38

From Ruth Lewis, Weston Rhyn, Shropshire, UK

Personalised care for those going through the menopause is a lovely idea, but at the moment I can only think of it as a pipe dream.

Right now, I can't get a doctor's appointment to talk about menopause care. This isn't official policy, just the result of having to go through a triage system mediated by receptionists, not medics, working with a tick-box system. Repeat prescription for HRT – yes. Someone just wanting to talk to their GP about that? Ask us next month, next year, whenever. Not now.

I am sorry to sound so downbeat, but the ideas in your article seem separated from reality. Menopause care is a huge issue, which needs a real solution, but getting there will require changing attitudes and systems so entrenched, it is hard to imagine how that could happen.

Quantum rethink throws up incredible possibilities

27 August, p 46

From Alan Wells, Saltdean, East Sussex, UK

Vlatko Vedral's article about rethinking quantum theory offers the chance of "a route back in time" mediated by the possibility that the "younger and older versions of [a] particle are simply entangled in time".

Of course, this could never be applied to an entire human body, but the theory that consciousness arises from quantum effects in microtubules in the human brain raises the question of whether such entangled particles could be present there.

Might this allow for the transmission of a small amount of information from an older self to a younger self, an act which could lead to changes in history and perhaps even the generation of an alternative reality?

From Donald Windsor, Norwich, New York, US

Once a projectile is fired, where it lands seems already determined. Does that mean the landing spot is entangled with the projectile when it was fired from the gun? Is the projectile in the past entangled with itself when it hits the landing spot in the future? Am I, as an older man, entangled with myself when I was born?

There is a better way to judge food's eco cred

13 August, p 13

From Geoffrey Patton, Silver Spring, Maryland, US

You described a herculean, reductionist analysis assessing foods' environmental impact. There is another green metric: price. It generally reflects energy and resource inputs. Even if pollution costs are externalised, price can act as an approximate green metric. The challenge is to add externalised costs, such as pollution, to the price.

Are Australia's favourite trees taking revenge?

27 August, p 38

From Geoff Harding, Sydney, Australia

Contemplating possible sentience in plants can lead one to imagine some strange possibilities.

A magnificent species of Australian eucalyptus tree – the river red gum – recently topped a survey to be Australia's favourite tree. However, it has a reputation as a "widow maker" due to its propensity for dropping huge branches that may land lethally on people in the forest, in particular on timber cutters.

The standard explanation is that the trees self prune like this to conserve water, but one may wonder if the branch dropping is more frequent as a self-defence strategy when timber cutters are working in the forest.

From Mike Vandeman, San Ramon, California, US

Most writing on consciousness misses the point. All life is conscious, but each organism is conscious of different things.

Bacteria are conscious of certain chemicals. Plants of chemicals and electricity. I am conscious of weight and various frequencies of light.

From Mark Stewart, Neptune Beach, Florida, US

Your article posits that the *Mimosa pudica* plant's reaction to anaesthesia may represent plant sentience. However, a reduction in the mimosa's response to stimuli under anaesthesia doesn't imply a human-like consciousness. The more likely, and more interesting, possibility is that putting a plant to sleep may point to a similarity in chemosensory systems over a broad range of organisms.

Give up the eternal chase for a fusion power plant

20 August, p 12

From Peter Bursztyn, Barrie, Ontario, Canada

I read the article about ignition in a nuclear fusion experiment with dismay. The experiment produced enough energy to sustain itself – theoretically. However, it lasted just "100 trillionths of a second" and couldn't be reproduced.

And this is just heat energy. Before it can be truly useful, heat must be converted into electricity, and we haven't even begun to design methods to remove heat from a fusion reactor.

We already know how to convert solar energy to electricity. We also know how to convert wind energy, itself derived from solar input, into electricity. And there are many proven ways to store electricity when there is neither sun nor wind.

Unfortunately, humans are attracted by the new and shiny. If the immense amount of money spent on nuclear fusion research had been directed toward building equipment to generate and store renewable energy, Vladimir Putin's threats to turn off Russian gas would have lost some punch.

From Alec Mitchell, Vancouver, British Columbia, Canada

Can a nuclear physicist please explain why we are spending so much on the seemingly hopeless quest for a fusion reactor when there is a highly reliable, cost-free one in the sky delivering more than enough fusion power for the entire planet?

Good reasons why AI won't crack ancient script

Letters, 20 August

From Otta Wenskus, University of Innsbruck, Austria

Maureen Clayson asks whether AI could be used to crack the ancient script known as Linear A. The answer is not yet, and probably never, because we have too few texts and they are written in an unknown language. Insufficient data, in other words. ▮

For the record

- **The area modelled to assess earthquake risk in California was about 1 million square kilometres (27 August, p 8).**
- **We incorrectly stated that isopropanol was an extract of black cohosh. Isopropanol shouldn't be ingested. Extracts of the plant black cohosh have been used to treat menopausal symptoms (3 September, p 38).**

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The rise and rise of YouTube

Over 17 years, YouTube has transformed from a place to share home videos to a cultural juggernaut. A must-read book follows its journey, finds **Chris Stokel-Walker**

Book
Like, Comment, Subscribe
Mark Bergen
Penguin Business

INSIDE CREATIVE HOUSE/GETTY IMAGES

THE sheer scale of YouTube is inescapable. The site is the world's biggest video-sharing platform, a veritable Alexandrian library for the digital 21st century and a de facto search engine for billions of people worldwide.

Its position in our lives is all the more extraordinary when you consider its age: if YouTube were a person, it would be unable to drive in many countries, and still couldn't legally drink in the UK, US and Australia.

In *Like, Comment, Subscribe: Inside YouTube's chaotic rise to world domination,* Mark Bergen takes on a big task.

He peels back the public relations spin that Alphabet – the parent company of YouTube and Google – promotes about its platform, and shows the scrappy ascent of a site that started out as a place for funny home videos but is now a former of public taste, with an influence that can help presidents into power and fuel waves of rebellion worldwide.

It is a riveting read, taking us behind the scenes of the platform's rise from nothing to its purchase by Google, and inside the minds of the flawed, often in-over-their-heads people who created corporate global policy on the hoof.

We see pool parties with executives, tense meetings with advertisers and text messages and emails pinging back and forth as YouTube lurches from crisis to crisis.

For anyone really wanting to know how YouTube came to be so dominant, the book is a must-read, unparalleled in its access to the inner thoughts and workings of the people and departments that dictated what content can be seen and what can't.

The book is marketed as the definitive account of YouTube, so I should declare an interest here. I have also written a book on YouTube, published three years ago. Bergen clearly had even more access than I did, as he delves far deeper into the inner machinations of the video giant's operations, giving unprecedented, enlightening insight into how major decisions were made.

> "The focus on being a fly on the wall during the rise of YouTube and some of its biggest challenges has costs"

For example, we learn more about the 2017 "adpocalypse", where major advertisers pulled their cash from YouTube over concerns that their products were being shown alongside unsavoury videos. This cost the site \$2 billion in revenue – alongside a \$26 billion hit to its share price.

Then there are revelations about how YouTube reprimanded some of its biggest stars, PewDiePie and Logan Paul, on calls after major controversies.

Yet that focus on being a fly on the wall during the rise of YouTube and throughout some of its biggest challenges has its costs. For example, it means there is less space devoted to bigger questions about the always-online world of creators, and the impact a diet made up of more YouTube than mainstream media has on society.

The effects are often hinted at, however, through clever devices. For instance, Claire Stapleton, who became known as the bard of Google for her picaresque internal missives, acts as a sort of Greek chorus throughout the book.

YouTube creators can have enormous influence over popular culture

Her increasing unease at YouTube's power and her own position in an ever more corporate company aren't always elucidated fully. Instead, the book recounts how Stapleton asked herself the deeper question: is YouTube actually net negative or net positive for society?

She never fully reaches a conclusion – nor, really, can we. By focusing so much on the business, Bergen sometimes ducks those deeper questions.

Nonetheless, it is a vital, necessary, readable book if we are to understand how YouTube suffused our society, and to learn about the psychodramas of some of those who helped make this happen. ▮

Chris Stokel-Walker is a writer based in Newcastle, UK

Down the toilet

Every day, we flush away a key natural resource – human faeces. **Chelsea Whyte** explores a book challenging us to think again

Book
Flush
Bryn Nelson
Hachette

ASK me to name the world's best invention, and I will always give the same answer: the toilet. Its ability to whisk waste away to a safe place where potential pathogens and odours can do no harm isn't to be sniffed at. But an unusual book has convinced me that toilets make it too easy to waste our waste.

Bryn Nelson's *Flush: The remarkable science of an unlikely treasure* explains the many ways in which a precious natural resource, faeces, can be put to good use. Along the way, Nelson studs the important stuff with delightful facts. For starters, did you know that the average adult defecates about the weight of a pineapple every week? Well, you do now.

Anyone who has followed the recent success of faecal transplants to treat conditions such as irritable bowel syndrome or *Clostridium difficile* infections will know about their power to heal. But I didn't realise that the first known faecal transplant took place in China in the 4th century AD.

Modern medicine was hesitant to embrace these transplants, partly because the idea can trigger disgust. Nelson tells of people seeking the treatment who faced stigma, oddly stronger from doctors providing the treatment than in patients.

In fact, the fight against revulsion is key, says Nelson. At first, I thought he was pushing that argument too much, until I realised how much it was needed – people have died waiting for faecal transplants to be approved. We have manufactured this disgust in some ways: studies show it is worse in places with widespread modern plumbing and ceramic toilets.

> "These days, scientists pore through ancient latrines to reconstruct the diets and diseases of our ancestors"

Nelson's tone is fairly light as he asks us to confront a taboo subject, but he can go overboard with details of his solid emissions, including their texture, buoyancy and more. Elsewhere, a section on the microbiome – microbial cells that play a crucial role in health – gets wearing as he covers the tests he subjected himself to. As a former microbiologist, he may be more interested in the minutiae than I am.

Press on, though, and you find that shifting views on human faeces are revealing their power to explain the past. One anthropologist described how, as an undergraduate in the 1960s, he and his colleagues thought fossilised human waste was so unimportant they used it as a frisbee to see how far they could throw. These days, scientists pore through ancient latrines and human waste to reconstruct the diets and diseases of our ancestors. Some findings give us a sense of how the human microbiome has evolved, but others are just plain interesting.

Take what Nelson calls the "holy shit" of Danish bishop Jens Bircherod, found in a latrine from the late 17th century, which revealed the bishop's taste for local blackcurrants and peppercorns imported from India.

Then there are other modern uses of sewage, such as monitoring disease and drug detection – as explored in "Secrets in the sewers" (*New Scientist*, 20 August, p 42) – or using faecal matter to replenish soil nutrients. And human biogas, natural gas made from sewage, is being used to power sewage treatment plants.

Nelson has great historic tales of the use of excrement. In 12th century China, for example, catapults launched a mixture of gunpowder, dried human faeces and poison in ceramic containers, which was said to release toxic smoke on impact.

Reading each chapter, I found myself anticipating such tales, which remind us that whatever else we are, humans have always been resourceful – at least with our faeces. ▮

Clinical-looking modern toilets may help fuel unhelpful notions that faecal matter is disgusting

SHUTTERSTOCK/OASISAMUEL

Don't miss

Watch

Andor takes *Star Wars* fans back to before the events of *Rogue One*, and finds Cassian Andor (Diego Luna, above) doing all he can to avoid getting involved with a seemingly doomed rebellion. On Disney+ from 21 September.

Read

Stars in Your Hand, by Kimberly Arcand and Megan Watzke, shows how to make models of the cosmos using a 3D printer and 3D computer imaging. Luckily, it includes easy instructions for creating stars and more. On sale from 20 September.

Watch

Super/Natural, a six-part documentary series, reveals animals' superpowers, from glowing squirrels to bull elephant seals (pictured) that detect love rivals through the sand. Streaming on Disney+ from 21 September.

TOP: LUCASFILM LTD; BOTTOM: NATIONAL GEOGRAPHIC FOR DISNEY+/JOEL WILSON

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Possible futures

In globally uncertain times, we need to think clearly about the future. **Elle Hunt** looks for help in a book with an ambitious, multi-lens approach

BRIAN JACKSON/ALAMY

Book
Future Stories
David Christian
Penguin Random House

NOW more than ever, it feels like the future is uncertain: the times, they are unprecedented. Adam Tooze, an economic historian at Columbia University in New York City, recently described the global outlook as a “polycrisis”, remarkable not only for the number of risks currently active, but also their volatility.

As well as the pandemic, we have the invasion of Ukraine, inflation, pressures on food and energy markets and upheavals in global politics. Even such sober commentators as the Bank of International Settlements emphasise the lack of parallels for this moment in history.

When there is little to glean from the past, it is a relief to be told how to think about the future. David Christian, whose *Origin Story* was a bestseller in 2018, has now turned his gaze towards the horizon.

Future Stories: A user’s guide to the future is Christian’s latest entry in the annals of Big History, the field he pioneered as a professor of history at Macquarie University in Sydney, Australia. It combines disciplines from science and the humanities to make sense of humanity’s relationship to the cosmos, all the way back to the big bang and on into future.

This book is no less ambitious, but with more emphasis on “futurecasting”. As Christian shows, this is something humans and other species have always attempted. Living organisms are in one way defined by their fight to survive, so they “meet the future actively, with discrimination and purpose”, he says – whether it is an antelope avoiding a water hole frequented by lions, or a plant determining when to flower.

In a fascinating journey into another organism, reminiscent of Peter Godfrey-Smith’s writings on the octopus in *Other Minds: The octopus and the evolution of intelligent life*, Christian takes us inside an *E. coli* cell. Though it is just a few millionths of a metre long, he says it demonstrates a sophisticated probabilistic “thinking” evolved over millions of years that enables it to survive.

From the questions asked of the oracles in ancient Greece to the famous wager by 17th-century mathematician Blaise Pascal on the existence of God, *Future Stories* is rich with insights into how we conceived of and managed the future in the past.

> **“In thinking about the future, the tendency is to inflate both the innovations and the devastations facing us”**

But the “user’s guide” of the subtitle is Christian’s real focus. He had been teaching his course on Big History, and was spurred to write *Future Stories* to aid his own understanding. As one student told him, not to explore what’s next left them on a cliffhanger.

Facing the scenarios ahead is vital – while we can still do something

The challenge of thinking about the future, he writes, is finding “the sweet spot between generality and precision”. When imagining 100 years into the future, or even 50, we often envision more radical transformation than is likely, or even possible. The tendency is to inflate both the innovations and the devastations facing us. It clouds our view of the likely or even possible realities ahead, and prevents us from acting on them.

Echoing Tooze, Christian warns we face a turning point. During the so-called Anthropocene, we have experienced more rapid change than ever with new technologies and expanding networks. Then factor in this: human populations are expected to peak at between 9 and 12 billion later this century.

These changes have accelerated to a state where “nothing seems stable”, says Christian. For him, one important barrier to thinking about the future is the assumption of its stability: it is crucial that we confront all the scenarios and dangers facing us while we may still be able to do something.

This thought may be more daunting than facing facts, even when they hint at instability, says Christian, pointing to philosopher Toby Ord’s attempt to calculate the probability of “existential catastrophes” from pandemics, asteroids and the like. Ord’s very rough estimate was a likelihood of 16 per cent, or one in six.

This seems high until you recall that most dangerous threats arise from technological and economic overreach, says Christian, which in theory we can control. “Like all gamblers, we face a delicate choice,” he writes. *Future Stories* not only shows how we have approached such choices through history – it helps us to understand the odds. ▮

Elle Hunt is a writer based in Norfolk, UK

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BIG THINKERS SERIES
SEAN CARROLL

The coming plastics revolution

Most plastic ends up in landfill or incinerators. But the emergence of an innovative recycling technology is set to change the way we think about plastic

One of the lesser-known uses of plastic is to reduce carbon emissions. For example, plastics make vehicles lighter thereby increasing their efficiency; it also increases the shelf life of foods, reducing food waste and the need to transport more. So plastics have an important role to play in creating a sustainable future—provided they can be manufactured sustainably themselves.

Currently that isn't the case. Of the 24.5 million tonnes of plastic waste generated in Europe each year, only 14 per cent is recycled. The rest is incinerated, buried as landfill or lost on land or at sea. Indeed, the European plastics industry emits 95 million tonnes of CO_2 each year, about 3.7 per cent of total emissions. A third of this comes from incinerating waste plastic.

That has to change, says Marc van den Biggelaar, Advanced Recycling Director EMEAI and APAC for Dow, one of the world's leading chemicals and plastics manufacturers. "With a growing population, we need to find a way to make better use of our resources."

So Dow has come up with a plan. In partnership with the recycling technology company, Mura Technology, it wants to revolutionise the plastics economy by dramatically increasing the amount of plastic that is recycled while also reducing carbon emissions. The goal is to make plastic a net zero product that is entirely circular.

The approach will change the way we make plastic and even how we think about its value to society. And the stakes could hardly be higher: the health of the planet is on the line.

Today most plastic is made from petrochemicals extracted from the ground, using processes powered by fossil fuels. While a great deal is discarded, a large proportion of plastics waste can be collected and sent to be mechanically recycled This

Clockwise from top left:

Carolina Gregorio, Dow
Marc van den Biggelaar, Dow
Peter Sandkuehler, Dow
Oliver Borek, Mura Technology

UT07/ISTOCK

Advanced recycling produces virgin-grade plastics suitable for food packaging

involves washing, drying and grinding the material, then heating and reforming it into a new product. But at no stage is the chemical structure of the plastic changed.

Mechanical recycling makes up the vast majority of current recycling. However, careful sorting is necessary and the process does not work for all plastics. Mechanical recycling also tends to downcycle materials because contaminants make the recycled product lower quality than the original. That prevents it being used for certain applications, such as food packaging.

"You need to have material that is food-contact approved and meets safety requirements, and mechanical recycling can't deliver that today at scale," says Peter Sandkuehler, Director Sustainability EMEA at Dow.

Mura Technology's advanced recycling process changes this calculus. It uses supercritical steam to break down plastic into its constituent hydrocarbon molecules. Crucially, this works for plastics that can't currently be recycled mechanically. "Using water allows us a lot of flexibility around the types of waste plastics we can process," says Oliver Borek, Chief Commercial Officer, Mura Technology.

Advanced recycling produces a wide range of hydrocarbon products that can replace petrochemicals currently extracted from the ground. But they must be further processed before they can be turned into plastic.

For example, Dow takes a light oil, called naphtha, and breaks it down in a process known as cracking. This creates smaller molecules, such as ethylene, which is a feedstock for commercial polyethylene production. The polyethylene can then be fashioned into more or less any plastic product.

> **"The goal is to make plastic a net zero product that is entirely circular"**

So products that have been thrown away become the feedstock to make virgin-grade plastic that is just as good as the original. This creates circularity in the plastics value chain.

Historically, the plastics economy has been linear. "People haven't given much thought to plastics after they're past their usefulness and those plastics have found their way into landfill and incineration," says Borek. Such an approach is not sustainable, he adds.

Advanced recycling will not replace mechanical recycling. It will instead use plastic waste that currently cannot be used by mechanical recycling, says Borek.

Together, Dow and Mura Technology have ambitious goals. A new facility in Boehlen, Germany, is set to recycle a predicted 120 kilotonnes (kT) of plastic per year and play a significant role in Dow and Mura's planned global rollout of 600kT of recycling capacity by 2030.

There are other ways Dow plans to make plastics manufacture more sustainable. For example, the cracking process takes place at high temperatures that are currently generated by burning fossil fuels. In the future, Dow plans to make its crackers electric so they can be powered from renewable resources, such as wind and solar power, although this will take several years to implement, says van den Biggelaar.

All this work sits within the broader context of the European Commission's Green Deal, a continent-wide drive to make all plastic packaging recyclable by 2030 and to achieve net zero carbon emissions by 2050.

The new partnership will help Dow meet those targets. Mura Technology will source waste plastics that can't be mechanically recycled and process them into complex hydrocarbons that Dow will reintroduce into its production processes, creating a circular plastics economy.

This should amplify carbon savings. Current plastic feedstocks come largely from oil extracted from the ground. Switching to circular feedstocks lowers this carbon footprint by reducing the CO_2 released when waste plastic is incinerated. It also lessens future reliance on petrochemicals and the carbon they can add to the environment.

By avoiding incineration, landfill and by decreasing fossil feedstock use, advanced recycling could help reduce carbon emissions associated with plastics manufacture by 43 per cent. And by working with Mura Technology to give waste plastic a new life, Dow is confident that this approach will pave the way for a more sustainable landscape for the European plastics industry in the years to come.

It is a mission that will take time. "The change we need to transform the traditional linear plastics economy into a circular one is massive," says Carolina Gregorio, Policy Strategy and Advocacy Director EMEA at Dow. "It needs investment, the collaboration of different stakeholders across the value chain, and more partnerships such as the one with Mura to make it happen."

But for her, there is little choice. The plastics industry must eliminate plastic waste and work to prevent climate change, she says. "We want to do this because there is no other way. The future of the plastics industry is circular."

For more information visit:
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RETURN TO THE MOON

PEOPLE ARE ABOUT TO GO BACK TO THE MOON FOR THE FIRST TIME IN 50 YEARS. It is no longer just a race to get there, but the start of a whole new era of lunar exploration and exploitation. Within a few years, we may see people taking steps on the moon again, mining precious resources and setting up long-term bases on Earth's constant companion. Over the next nine pages, we explore the reasons we are so keen to go back, the new technology that will take us there and what lunar settlement could mean for humanity

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COMMITMENT

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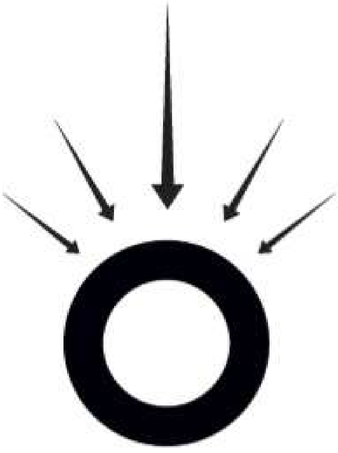
A DIFFERENT KIND OF SPACE RACE

This next phase of lunar exploration is a departure from what has come before in terms of ambition, the rationale for going – and the sheer amount of missions being planned



“AS I take man’s last step from the surface, back home for some time to come – but we believe not too long into the future – I’d like to just say what I believe history will record: that America’s challenge of today has forged man’s destiny of tomorrow.” These were some of the last words spoken on the moon as NASA astronaut Eugene (Gene) Cernan climbed the ladder back into his lunar module in 1972.

Contrary to Cernan’s hopes, no one has since set foot on the lonely, cratered world that orbits our own. But that is about to change, because the US is planning to send people back to the moon by 2025 and set up a permanent base there. Add to that the plans of China and other nations, not to mention the deluge of robotic missions, and it is clear that we are entering a new era of lunar exploration. The question is, after so many years, why now?

The decision to end the Apollo programme was made well before Cernan left his footprints on the moon. “Apollo didn’t end because it was too expensive or because it was unsustainable – the sunk costs were already sunk,” says Mary Lynne Dittmar, an influential figure in space policy at the firm Axiom Space. The adventures ended because Apollo was set up to win a politically motivated race, in which the US wanted to beat the Soviet Union to the moon. With that goal achieved, the moon was no longer a priority.

The forces shaping our return to the moon today are dramatically different. In the 1970s, every mission was an epic, do-or-die affair led by the US or the Soviet Union at incredible expense. Each project was defined in advance and then the machinery of the state would strain every sinew to make it happen. Today, the cost of going to space is lower, so many other nations and private companies can afford to get involved (see “Runners and riders”, page 40). Reduced costs also mean they can try missions out and see what works. In the past few years, China has ramped up activity, sending a probe to the far side of the moon, among other impressive feats. It has committed to a joint China-Russia robotic research station, and it says crewed missions are possible by 2030, though it hasn’t released firm plans for now.

One thing that hasn’t changed is that the US is still at the forefront of space exploration. NASA’s Artemis programme is taking centre stage. Its first mission, Artemis I, will be an uncrewed journey far beyond the moon using the purpose-built Space Launch System (SLS), the most powerful rocket ever built. It was due to launch earlier this month, but two attempts have been called off due to problems with fuelling. (As *New Scientist* went to press, the earliest planned launch date was 19 September.)

Still, if all goes well, the project is set to reach a momentous milestone in 2025 when another two people will follow in Cernan’s footsteps, including the first woman on the moon. “One of my deepest hopes, and obviously his, was that Gene Cernan would live to see us back there,” says Dittmar. Cernan passed away in 2017. “He almost made it.”

It would be easy to be sceptical about NASA’s ability to pull off these plans so quickly. After all, the agency has been here before. In 2005, it began a programme called Constellation, with goals that included sending humans to the moon by no later than 2020 and eventually on to Mars. It was binned in 2010. But there is a consensus in the space science community that Artemis is different. “Something that has doomed some other projects in the past has been that they’ve been US-only, but Artemis has momentum,” says Laura Forczyk at space consulting firm Astralytical. “I don’t think it would have gotten that momentum if it wasn’t for international partnerships.”

Artemis is one giant collaboration. Various components of the missions are being contributed by the European Space Agency, the Canadian Space Agency, the Japan Aerospace Exploration Agency and others. “That’s very different from Apollo,” says engineer Erika Alvarez, who is part of NASA’s Artemis team. The design and build of critical pieces of technology, such as moon landers and the planned moon-orbiting space station, will be contracted out to private companies. While the first flights will be powered by the government-owned SLS rocket, NASA’s plan is that some subsequent trips carrying cargo to the moon will be aboard Starship, a similarly huge rocket designed and built by Elon Musk’s company SpaceX. (It is vastly cheaper to run than SLS and some observers think it could and should end up replacing SLS entirely.)

You might ask why it has taken so long to get to this point. One reason is that humanity’s great space project for the past 20 years has been the International Space Station, a collaboration between the space agencies of the US, Russia, Japan, Canada and Europe. This taught us how to have people in space for extended periods. But equally, the time spent ignoring the moon has meant that many of ›

NASA

RUNNERS AND RIDERS

The key players lining up moon missions and what they are aiming to do

US

The US has the most ambitious goals, with NASA's Artemis programme aiming to return people to the moon by 2025. The agency also plans a sequence of increasingly complex missions throughout the 2020s, with rovers, surface bases, power grids and an orbiting space station all featuring.

RUSSIA

Among Russian plans for the coming years are a rover project and a mission to return rock samples to Earth. The country's space agency, Roscosmos, has said the first mission, named Luna 25, will launch in 2023 and do research on lunar ice and dust.

CHINA

Recently, China has carried out a series of impressive lunar missions, including sending the first probe to the far side of the moon (see timeline below). It also says it wants to put people on the moon, perhaps by 2030. And in 2021, China and Russia agreed to build the International Lunar Research Station, a facility on the moon staffed by robots. The aim is for it to be operational by 2036, and humans could go there eventually.

INDIA

India has sent several robotic missions to the moon, but has no plans for crewed missions as yet.

JAPAN

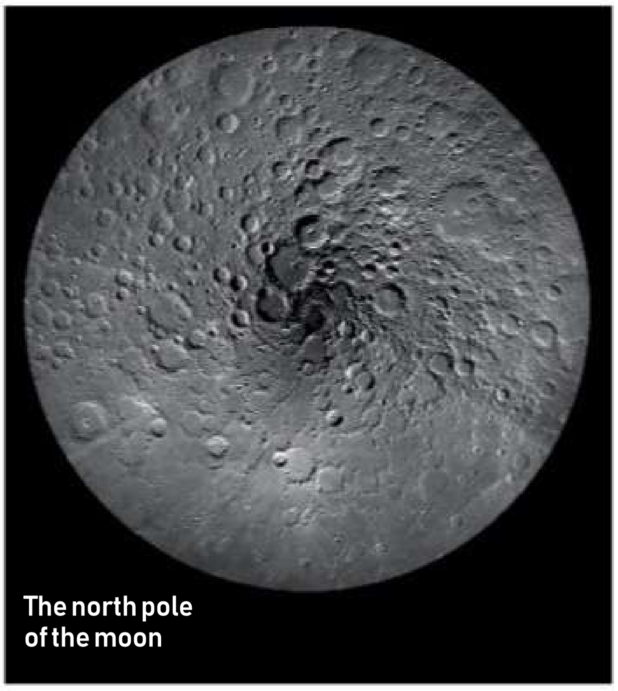
Japan's Lunar Exploration Program sent a rover to the moon in 2007, and several other robotic missions are in the works. The long-term goal is to have Japanese astronauts participate in a future international moon base.

EUROPE

Both through the European Space Agency and its many private space companies, Europe is working with the US on Artemis. Canada's space agency is doing likewise.

PRIVATE FIRMS

Companies will also play a crucial role in the Artemis missions. SpaceX is a linchpin in the plans, as its Starship rocket should carry equipment to the surface. Amazon founder Jeff Bezos's company Blue Origin is developing a vehicle called Blue Moon to land cargo or people. Many other companies plan to go to the moon too.


The north pole of the moon

NASA/GSFC/ARIZONA STATE UNIVERSITY

the engineers who worked on the Apollo missions have retired or died, and some of that expertise has to be rebuilt through extensive testing of the new hardware and processes. "There are some things that were learned the hard way that you don't want to learn again the same way," says Dittmar.

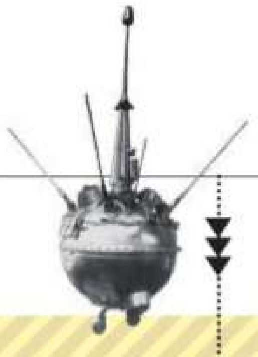
It isn't just the rocket that has to be tested – a massive amount of new technology will be required too (see "Home, home on the moon", right). "We're doing everything from food technology, to modifying our toilets so that they're built to last, to the environmental control systems," says Alvarez.

To say it is a tricky task would be an understatement, which might make some people wonder: why bother going back at all? There is the chance to cash in on lunar

70 years on the moon

The space age began as a race between two state powers. These days, many nations and private companies are involved and the pace of exploration has ramped up. These are some of the most important missions, past, present and future

1959



Luna 2
Soviet Union
After several failed attempts, this probe was the first object to reach the surface of the moon, crashing into it

1964

Ranger 7
US
The first US mission to land on the moon. The probe sent back close-up images of the surface

1966

Surveyor 1
US
An uncrewed lander that gathered data about the lunar surface needed for the Apollo missions

1968

Zond 5
Soviet Union
A probe carrying two live tortoises, flies and plants. It circled the moon twice before returning its payload – still alive – back to Earth

JULY 1969

Apollo 11
US
Neil Armstrong becomes the first person to walk on the moon

−130°C Typical night temperature close to the moon's equator

resources (see "Cosmic capitalism", page 46). But if you ask NASA, it says its principle rationale is that returning to the moon is a vital precursor for a trip to Mars, where it wants to send a cadre of astronauts by the late 2030s.

The first people to visit Mars will face a nine-month trip to get there and they will have to stay for months before making the return journey. With that in mind, learning to set up an independent settlement on the moon will be essential before we can seriously contemplate a sojourn on the Red Planet. "The moon is a perfect platform to test all these technologies, the equipment, the maintenance and repairs – because from the moon, we can get back home," says Alvarez.

Some argue that sending people off world isn't worth the trouble. If the point is to explore and do science, send robots: they are much hardier and more adaptable than humans. They may not be able to interpret the landscape around them or do science quickly, but they can send pictures and data home.

However, as Dittmar says, perhaps the renewed thrust to send people back to moon is just human nature: our species loves to explore. "Why in the world would you get into something called a boat and go over water when you can't swim through it?," she says. "Why would you go through a mountain pass or over an ice bridge? There's something in our make-up; it makes sense to us biologically. All that's happened now is that our technology has evolved the same way it did to take us out of Africa and across oceans, and now it's evolved to take us off the planet. I don't see it as any different from the rest of human history." **Leah Crane**

HOME, HOME ON THE MOON

NASA's plans to return people to the moon and build a long-term base there will require a plethora of new technology.

THE most powerful rocket ever built sits on a launchpad in Florida. Over an intercom, crowds of onlookers listen to the countdown – "4, 3, 2…" – and then the bottom of the rocket begins to rumble. The vibrations first travel through the soles of the watchers' feet and then hit their bodies like an ocean wave. Jets of steam and fire ricochet off the concrete, and suddenly the rocket is blasting skyward. The astronauts within watch the countryside shrink below them as they begin their journey to the moon.

This scene could be from six decades ago – or it could be from just a few years in the future. The launches of the Artemis missions that the US hopes will soon return people to the moon will look very similar to the Apollo launches of the 1960s. But that is where the similarities end. "Apollo was awesome, but a lot of it was to just prove that we could do it," says NASA's Steve Creech. "I'm not saying it wasn't important, but this time we want to do it in a way that's sustainable and that leads to next steps." In other words, this isn't just about going back to the moon. It is the first glimmerings of what many hope will be a sustained campaign of human space exploration.

NASA's plans could hardly be bigger. They feature astronauts on moon buggies and long-term bases with power grids and mining operations. And with the first steps already being taken, this is set to happen by roughly the end of the decade. All of which seems wildly ambitious – and begs the question, what fresh technologies will such adventurous feats require?

To begin with, the Artemis missions will largely be repeating feats managed during the space race. Artemis I will pass 100 kilometres above the moon's surface and orbit for several days, allowing the Orion craft – the capsule intended to carry astronauts – to be tested in space. Artemis II, planned for 2024, will involve a crewed fly-by of the moon. Then, in 2025, the third mission in the programme is set to see people land and walk on the moon again, including the first woman to do so. "I think that seeing women, people of colour, the next generation, walking on the moon can ›

NOVEMBER
1969

Apollo 12
US
Astronauts Charles Conrad and Alan Bean land on the moon

1970

Luna 17
Soviet Union
The first robotic rover on the moon

FEBRUARY
1971

Apollo 14
US
A crewed mission to a more mountainous area. The astronauts collected almost 43 kilograms of rock

JULY
1971

Apollo 15
US
The first mission to use a lunar rover vehicle to explore the surface

APRIL
1972

Apollo 16
US
Astronauts spent almost three days on the surface doing science and exploring

DECEMBER
1972

Apollo 17
US
Gene Cernan walks on the surface – the last person to do so

AUGUST
1976

Luna 24
Soviet Union
A lander that returned samples of moon rocks to Earth

CCCP

1980s

No moon missions were launched in this decade

1990

Hiten
Japan
Japan's first space probe orbited the Earth and moon for three years before being crashed into the lunar surface

What will life be like on the moon?

The moon's south pole, 2037. NASA and its contractors have built a habitation staffed by a rotating crew of astronauts, much like the International Space Station was until it was shuttered in the 2020s. There is a power grid of solar panels and several rovers parked outside. When the crew look out of the windows, they can just make out the water ice mining station in permanent shadow at the bottom of the nearby crater.

Life here is no cakewalk. Because of the moon's slow rate of rotation, astronauts will face periods of two weeks of complete darkness and temperatures dipping below -173°C (279°F), followed by two weeks of around-the-clock sunshine and temperatures above 100°C (212°F). It means sleep can be a challenge and going outside to make repairs and do science is dangerous.

The crew handle this by planning their outdoor adventures to coincide with the lunar dawn, when temperatures are more reasonable. Their suits are also specially designed to reflect sunlight and resist heat, plus they have cooling systems inside. One of the best things, they all agree, is that the suits are tailor-made, rather than coming in standard sizes like in the Apollo era.

The time delay for communications to Earth is just over a second, so they can place a video call home whenever they like and see their families' faces. Occasionally, rich space tourists pay them a visit and the astronauts have to smile for a selfie.

> **"THE PLAN IS TO LAND NEAR THE MOON'S SOUTH POLE, WHERE THERE IS ABUNDANT WATER ICE"**

do a lot of the things that it did in the 1960s, can inspire people to go into science and drive the technical state of the art," says Lori Garver, a former deputy administrator of NASA.

From here, the plan is for things to change radically. For starters, NASA aims to put a space station known as Gateway in lunar orbit. The idea is that this will allow a reusable lander to shuttle between orbit and the surface, making trips to the moon's surface cheaper and easier. The agency has already contracted the aerospace company Northrop Grumman to build two founding components of Gateway: a place for astronauts to live, known as the Habitation and Logistics Outpost, and a segment to provide power and propulsion. Artemis IV, which may launch in the second half of the 2020s, will carry these components into lunar orbit. Artemis V, the last mission NASA officially has planned (with no set date as yet), will be the first to see humans drive a rover on the moon. It will also deliver a new refuelling module to Gateway, built by the European Space Agency and partner companies.

Aside from all that new infrastructure, the science carried out on these missions will be different too. The plan is for the Artemis landings to be near the moon's south pole, which is of particular interest because of its abundant water ice (see "Going off piste", right). Astronauts staying on the moon will need a local supply of drinking water, as it is too heavy to transport from Earth. What's more, water can be split into oxygen and hydrogen, the first being vital for breathing and the second for fuel to power the rockets that could potentially launch from our lunar staging post to Mars and elsewhere.

The moon's water ice is far colder than the ice cubes in your freezer and it is distributed through the lunar rock. Understanding how the ice behaves and how we can best make use of it is going to be crucial, and it will require a host of new technologies. Investigations are due to begin later this year, when a robotic lander called Nova-C – a partnership between NASA and US aerospace firm Intuitive Machines – will try drilling almost a metre into the lunar "soil" to extract and analyse the ice.

The next step will come when humans return to the moon as part of Artemis III. A key element of their mission will be to retrieve ice samples and bring them back to Earth, where they can be more thoroughly analysed. That might sound simple – we have freezers, after

1994

Clementine

US

A probe that tested how communications equipment and sensors responded to long-term exposure to deep space. It also observed an asteroid called 1620 Geographos

2003

SMART-1

Europe

This probe orbited the moon for three years. Among other things, it discovered deposits of calcium and high points on the moon that are in constant sunlight

2007

SELENE

Japan

Japan's second lunar probe, which, among other things, performed sensitive measurements of the moon's gravitational field

2007

Chang'e 1

China

A lunar orbiter that conducted the first microwave imaging of the moon

2008

Chandrayaan-1

India

This mission included an orbiter and impactor, making India the fifth nation to reach the moon's surface. The orbiter made high-resolution maps of the moon's mineral composition

2009

Lunar Reconnaissance Orbiter

US

Created high-resolution maps of the surface to aid future missions, for instance by assessing landing sites

2010

Chang'e 2

China

A similar mission to Chang'e 1, laying the groundwork for future missions

CCP

120°C Typical daytime temperature close to the moon's equator

Going off piste

Apollo-era missions stuck mostly to a small, relatively hospitable area of the moon's surface. Now, we are set to explore far more widely

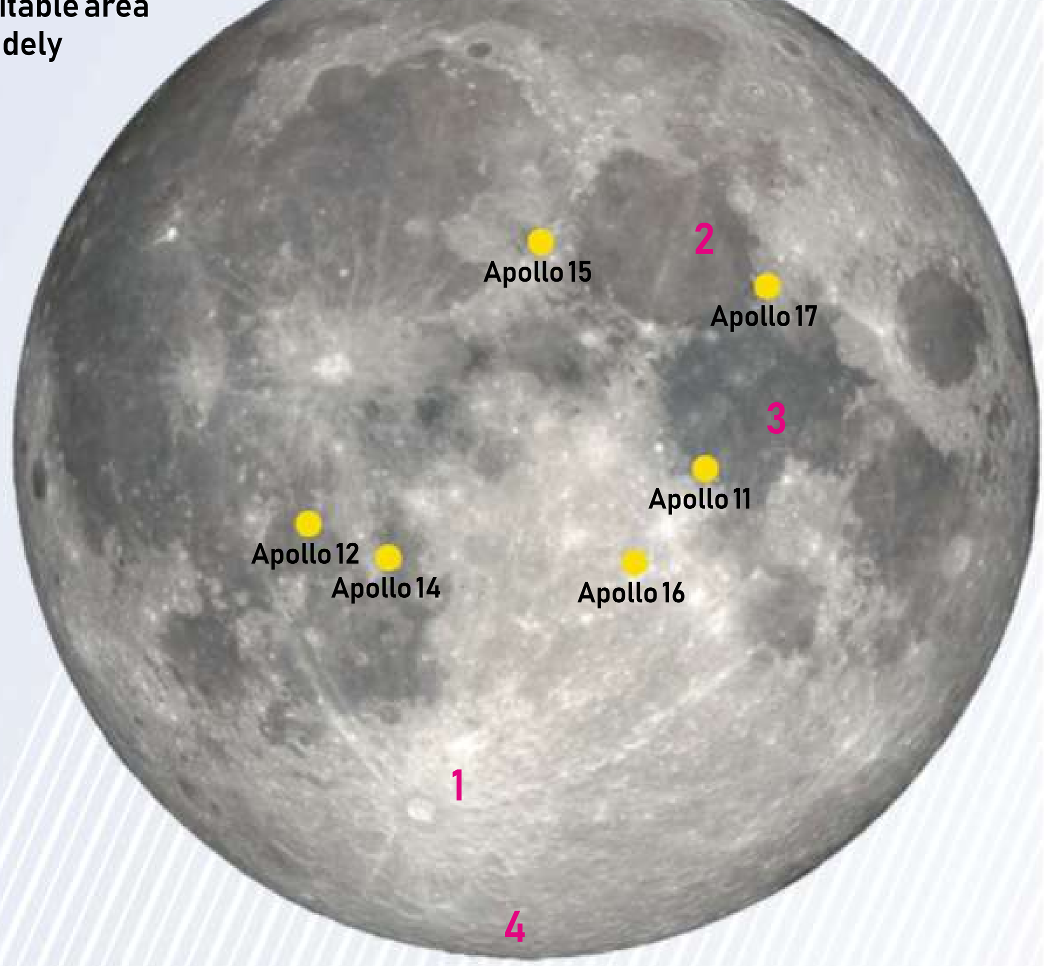
1. VIPER rover landing site
NASA has selected Nobile crater to be the landing site for its robotic VIPER rover in 2024. This will hunt for water ice and other resources. Nobile is in almost permanent shadow, making it one of the coldest places in the solar system. The crewed Artemis missions will probably land near here too.

2. Beresheet crash site
In 2019, this craft from private firm SpaceIL crash-landed on the moon while carrying a cargo of microscopic animals called tardigrades. Notoriously hardy, there was speculation that they could have survived – though subsequent experiments suggest the impact would have smooshed them.

3. Titanium deposits
In 2011, NASA's Lunar Reconnaissance Orbiter produced a map of the moon that revealed the elements on its surface. Among other useful deposits, it found that rocks in the Sea of Tranquillity contain large amounts of titanium, with some areas holding 10 times more than typical Earth rocks.

4. Water ice
Successive studies have shown that shadowed, cold areas of the lunar surface – an area totalling about 40,000 square kilometres – should contain water ice. Astronauts could harvest this to produce oxygen to breathe and hydrogen fuel.

● **Apollo landing sites**



all. But we will need to invent a special kind of freezer. "The samples will have to be kept extremely cold at all times, so those freezers need to be able to be transported between all of our vehicles and stay cold," says Erika Alvarez, part of NASA's Artemis team.

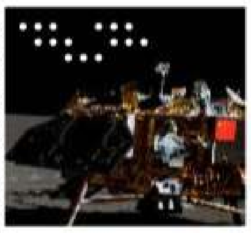
Eventually, the plan is to construct a surface habitat called Artemis Base Camp so that astronauts can remain on the moon's surface for days or perhaps even weeks, collecting samples and data. And though it might seem like a small step from spending a few hours on the surface to staying for a few days, it requires a huge leap in technology.

Before they can even begin to build a base, the explorers will need a power grid. Solar power will be possible, but the base will have to stay operational through periods of darkness lasting about two weeks. Temperatures during these periods can dip below -173°C (279°F). "You've got to have a grid that can sustain itself in that environment, that can generate enough power to do everything from life support to literally keeping the lights on to operational support," says Mary Lynne Dittmar at private firm Axiom Space. NASA is working with the US departments of energy and defence to develop a small nuclear power plant for the base.

Once power is established, there is the problem of actually constructing the base. ›

2013

Chang'e 3
China
A robotic lander accompanied by a rover called Yutu



JANUARY 2019

Chang'e 4
China
The first-ever craft to land on the side of the moon that is always facing away from Earth. It included a "moon garden" in which cotton seeds briefly sprouted

APRIL 2019

Beresheet
Private
This craft from firm SpaceIL crash-landed on the moon. It was carrying notoriously hardy creatures called tardigrades. Experiments have since suggested that they would probably have been mushed on impact

2020

Chang'e 5
China
A lander that collected samples of moon rock before returning them to Earth. A little water was found in the rock. The first sample-return mission to the moon since the Apollo era

AUGUST 2022

Danuri
South Korea
A mission that plans to image the moon using polarised light

AUGUST 2022

CAPSTONE
US
This recently launched lunar orbiter will test the stability of the planned orbit for the Gateway space station around the moon

US

SEPTEMBER 2022

Artemis I
US
First test flight around the moon in this programme

Love space? Visit New Scientist Live to hear planetary scientist Emma Bunce on exploring Jupiter's icy moons newscientistlive.com

When it comes to space flight, mass is everything – it isn't feasible to send all the materials to build an entire base camp, along with tools, supplies and astronauts, to the moon. Instead, several teams of researchers are evaluating how we might make building materials from the resources that will be readily available on the moon. This might mean mining stone, making bricks from lunar dust or even 3D printing with materials made from dust.

The trouble is that handling moon dust is tricky in the extreme. Because there is no wind or rain to smooth the particles, they are spiky and electrostatically charged, meaning they stick to everything, including spacesuits and tools. We know from the Apollo missions that it is tough to keep moon dust out of airlocks – and once it is inside, it can be breathed in, causing "space hay fever". NASA is already working on dust mitigation strategies, from nanocoatings for equipment to special filtration systems for habitations. All of which is a reminder that everyday life for astronauts on the moon will be far from straightforward (see "What will life be like on the moon?", page 42).

So how hard will it be to build a home on the moon? Very, is the short answer. As well as designing all this new technology, we will have to make sure it can withstand radiation from space. With no magnetic field to protect it, the moon is constantly exposed. One consolation, perhaps, is that at least the people who go the establish a base on the moon will have the option of coming home at speed if they need to. After another short countdown, they can fire their thrusters and be back within the embrace of Earth's atmosphere in three short days. **LC**

GUNS ON THE MOON

There are already signs that the moon is becoming a strategic military priority. Do we want soldiers anywhere near it?

CROUCHED in an area of permanent shadow, the soldier looks out over a landscape of craters and dust in a thousand shades of grey. A few kilometres away, the enemy's transportation buggy is parked in what they must have thought was a discrete location. But as they should have learned in training, tracking enemies is easier on the moon because tyre marks aren't eroded by the elements. Now all it will take is a squeeze of the trigger.

For now, scenes like this are, of course, distant science fiction. But it is fair to say military organisations are keeping an increasingly watchful eye on the moon. The US, Russia and China – competing powers on Earth – have ambitions to send missions back to the moon in the next decade or so. They will all be heading for roughly the same place: the moon's south polar region, with its precious resources, such as water ice. Even before that, these nations have been sending up a steady stream of satellites.

With this renewed push for the moon, and the lucrative returns that might result, military interest is inevitably following. "The United States is certainly aware the moon could have tremendous long-term economic potential," says Peter Garretson, a defence expert at the American Foreign Policy Council, a US think tank. "The military doesn't want an outpost to be threatened due to the lack of a sheriff." Yet even in these tentative early stages, there are concerns that military activity could snowball. If we are to return to the moon, how much of a role, if any, are we comfortable with the armed forces playing?

US military interest in lunar space dates back to the dawn of the space age. In 1959, the US Army proposed a crewed military outpost on the moon called Project Horizon. Notions of such bases, as well as nuclear testing on the moon, had supporters during the cold war too.

Those proposals never gained traction, but recently there has been more concrete interest and action. The US and Chinese militaries have spoken about conducting surveillance beyond Earth orbit for years, says space policy expert Bleddyn Bowen at the University of Leicester, UK. This would include things like using satellites to track debris from rockets in order to prevent collisions between spacecraft in lunar orbit. "If the moon is going to be a busier

2022

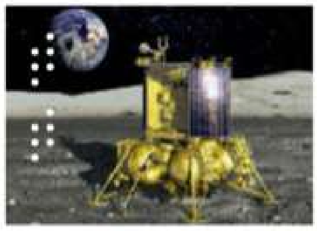
MAPP rover
Private
The company Lunar Outpost plans to collect lunar dust and transfer ownership of it to NASA, in the first-ever sale of space resources

2022

Asagumo
Private
UK-based company Spacebit plans to launch a small, four-legged robot to explore tunnels left by ancient lava flows

2022

Luna 25
Russia
A robotic lander designed to explore the moon's natural resources. Part of the Luna-Glob programme, which aims to build a robotic base on the moon



2023

Garatéa-L
Private
This probe from Brazilian company Airvantis is intended to measure the effects of cosmic rays on bacterial cells and human tissue samples, and image the far side of the moon

2023

Luna Zebro
The Netherlands
Lander to make measurements at south pole

ESA

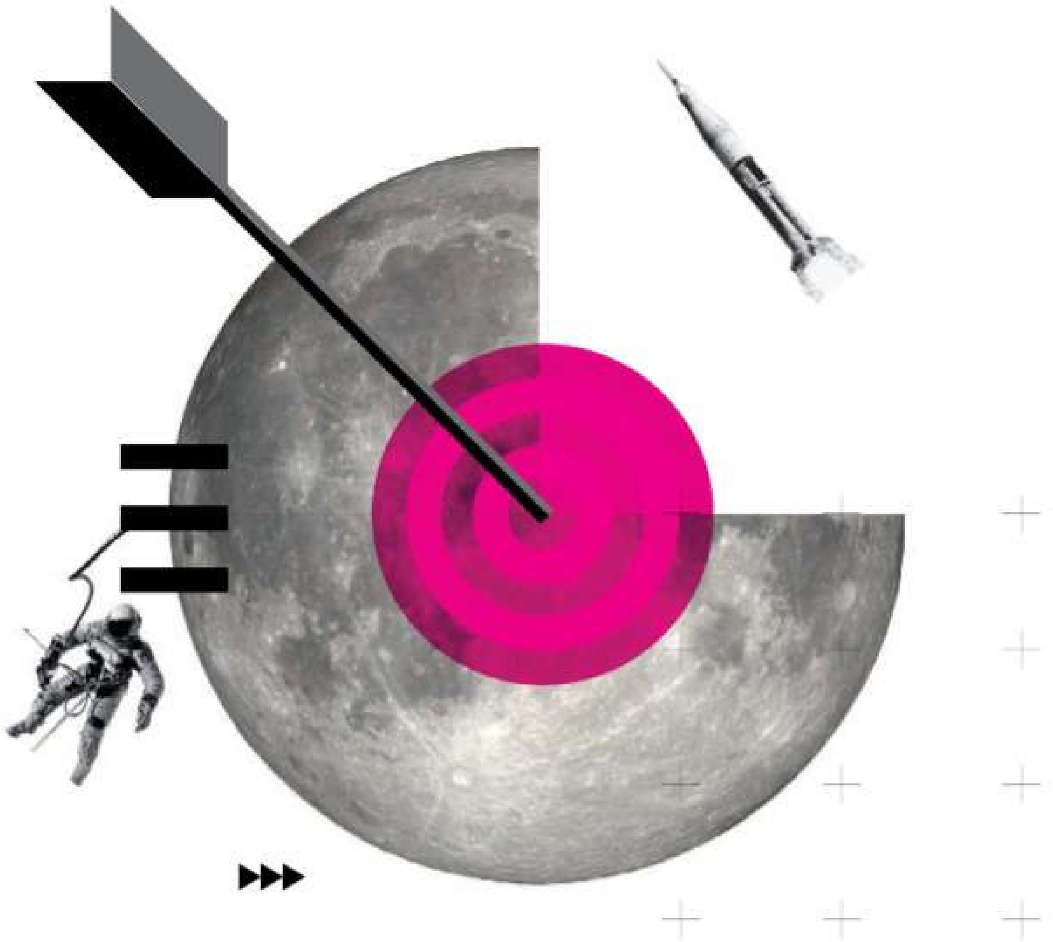
2024

Beresheet 2
Private
A planned follow-up to the 2019 mission from SpaceIL, with as-yet unclear objectives

2024

VIPER
US
A NASA rover aiming to visit the south pole and study the composition of its water ice in detail

6378 kilometres: The radius of the moon. A little less than a third that of Earth



NASA / RYAN WILLS

place, you're going to need more infrastructure to support it," he says.

Evidence for this came in March, when a discarded rocket booster, believed to be of Chinese origin, hit the moon, having been untracked for years following its launch in 2014. "Eventually there will be astronauts on the moon," says Vishnu Reddy, a space tracking expert at the University of Arizona. "The chance is very small of them getting hit by something. But we've clearly seen that it is a possibility." Part of the military's role in relation to the moon could be preventing such accidental impacts.

The US Space Force, the sixth branch of the country's military that was founded in 2019, is now taking action on this. In March, it announced it was developing the Cislunar Highway Patrol System (CHPS) satellite in collaboration with the Air Force Research Laboratory. The plan is for this craft to test technologies to track objects up to and beyond the orbit of the moon for the first time. Prototype proposals have been submitted, with a contract due to be awarded to a manufacturing company soon.

Experts agree that tracking of this sort will be useful. But it is "not clear why this has to be the military and not a civilian programme", says astronomer Aaron Boley at the University of British Columbia, Canada.

Having the US military involved in our future on the moon could lead to a scenario where the forces of other countries, such as China, feel the need to escalate their activity. There was an incident earlier this year in which US and Chinese satellites in a geostationary orbit about 36,000 kilometres above Earth came into close contact and manoeuvred to get a better look at each other.

"You've got the US and China each casting suspicions about what the other might do," says Brian Weeden at the Secure World Foundation, a US think tank that promotes the peaceful use of space. "That is going to send exactly the wrong signal."

Only the US appears to have made public its lunar military ambitions so far, though. "No one else has expressed a military interest in the moon," says Jonathan McDowell, an astronomer at the at the Harvard-Smithsonian Center for Astrophysics, US. "There's a danger that the rhetoric that the US military is playing with will generate military interest in the moon where there really is no need for it."

While Russia has been relatively lacklustre in terms of moon exploration lately, China is generating concern among some Western observers. China's ongoing lunar programme – which has included sending a rover to the far side of the moon – has already raised some red flags, says Garretson, with the West struggling to figure out what to make of the intentions of a civilian-built but military-run effort.

China's equivalent of NASA is the China National Space Administration, a civilian ›

2024

Chang'e 6 & 7
China
Two further robotic missions, one intended to carry out another sample and return, the other to visit the moon's south pole

2025

Lunar Polar Exploration
India and Japan
A mission to send a lander and rover to explore the moon's south pole

2025

Artemis III
US
NASA says it intends to land people on the moon again, for a brief visit at first, as part of its flagship lunar programme

2027

European Large Logistics Lander
Europe, Canada and Japan
A lander designed to deliver a large payload of food, air and water to NASA's burgeoning moon operations

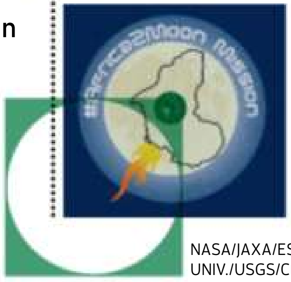
PRIVATE

2027

Luna 28
Russia
A sample-return mission destined for the moon's south pole

2030

Africa 2 Moon
South Africa
A crowd-funded mission masterminded by a non-profit based in Cape Town



2035

International Lunar Research Station
Russia and China
The two countries say they will collaborate to build an extensive moon base for scientific research, staffed by robots. The aim is for it to be operational by the middle of the next decade

NASA/JAXA/ESA/ISRO/NASA/JPL-CALTECH/BROWN UNIV./USGS/CNSA/SPACEIL/SPACEBIT/AIRBUS organisation. But the body actually in charge of human space flight is the China Manned Space Engineering Office, which is part of the military. Similarly, infrastructure such as launchpads and satellites are mostly run by the People's Liberation Army. China has also recently sent up a communications satellite called Queqiao (see timeline) and Garretson says this could be used for military applications.

Further in the future, the US envisages a more established presence on the moon, including business ventures (see "Cosmic capitalism", right). By that time, a military presence may be unavoidable, says Garretson. "The intent is to make sure we have eyes in that area and ensure freedom of operations, in order to deter anybody from thinking they could get away with some level of coercion, or blockade, or that sort of thing."

Others want to see more open discourse between the US and China. "I am worried that the lack of communication and the inclination to assume the worst is potentially going to create a bad situation," says Weeden.

We are unlikely to see troops on the moon any time soon. But within a decade, it is feasible that US and Chinese astronauts will be simultaneously operating there in close proximity, near to the south pole. Perhaps there will be valuable mining robots from other nations and companies too. "This is a good time to be figuring out how we're going to make this work," says McDowell. "Before it gets too fractious." **Jonathan O'Callaghan**

NASA

COSMIC CAPITALISM

Money-making ventures are going to be an essential part of our return to the moon. Who is to say what constitutes a fair deal in space?

NASA / IMAGE BY EVENING_TAO/ON / DILOKASTUDIO FREEPIK / RYAN WILLS

BILL NELSON, the administrator of NASA, grinned for the cameras as he handed over a cheque to Justin Cyrus, the boss of a company called Lunar Outpost. The amount? A mere 10 cents. This moment last year was partly a marketing gimmick. But in its own strange way, it was also a legitimately important milestone: it marked the first time that a government agency – or anyone else for that matter – had signed a deal to buy natural resources in space.

If all goes to plan, later this year Lunar Outpost will use a rover to scoop up some lunar dust, snap a photo of it, and officially transfer ownership of the material to NASA. In return, the agency will pay a further fee, this time 90 cents to make a round dollar.

The sums may be small, but this is the start of a new era for humanity, one in which the buying and selling of resources will extend beyond our home planet for the first time. And though Lunar Outpost looks set to be one of the first companies making money on the moon, it will be quickly followed by others. US plans to return people to the lunar surface rely heavily on partnering with companies.

There is just one problem. International space law is hazy about how business should work there and indeed if it is allowed at all. "This is uncharted terrain for sure," says space law expert Tanja Masson-Zwaan at Leiden University in the Netherlands. Outer space commerce is at an inflection point, and the precedents we set today could have far-reaching consequences.

Space law has long been dominated by the Outer Space Treaty, which was negotiated through the UN and first came into force in 1967. More than 100 nations are now party to it, including all the major space powers. It says the moon and other celestial bodies "shall be free for exploration and use". But what does that mean, exactly?

The US takes the view that "use" means people can mine resources in space, so long as they only profess to own the materials collected from their excavations. A few other nations, such as Luxembourg and the United Arab Emirates, have embraced this view too, in an effort to attract fledgling space companies. Others, notably Russia and China, have historically opposed such notions.

Exactly what kind of cosmic capitalism is permitted remained a moot point until about a decade ago when two companies, Planetary Resources and Deep Space Industries, announced plans to prospect for and mine water and precious metals on asteroids. This sparked debates at the UN's Committee on the Peaceful Uses of Outer Space (COPUOS) over the legality of their business models. The companies have since run out of money and been acquired by other enterprises.

Discussions have now settled in an extraction-friendly direction. "I think a consensus has been emerging in the past few years that owning resources isn't per se appropriation, hence not illegal," says Masson-Zwaan. "However, you need to ave a regulatory framework so that it's not a gold rush."

In May 2020, the US tried to deliver exactly this by unveiling a set of principles for the use of space called the Artemis Accords. These include promises to share data openly, preserve historical areas like the Apollo landing sites and assist astronauts of all stripes in emergencies. Agreeing to the accords allows countries to participate in the US's lunar plans, giving them greater access to scientific expertise and potentially allowing them to reap technological benefits. Signatories to the pact – of which there are now 21, including countries as diverse as Colombia, Singapore, France and Bahrain – must also accept the US interpretation of international space law regarding resource extraction.

NASA's deal with Lunar Outpost was a continuation of these US efforts to set precedents for how businesses can operate in space. But what will Lunar Outpost actually do up there to make money?

The company plans to land its rover, the Mobile Autonomous Prospecting Platform (MAPP), on the moon by late 2022. It will aim for the lunar south pole, which is also a target landing site for the Artemis missions to return people to the moon. The area is known to host plenty of water ice, which will be needed to help keep astronauts hydrated among other uses (see "Home, home on the moon", page 41). MAPP will use its perforated wheels to collect fine lunar regolith, or dust, and store this in its body. Lunar Outpost will then send NASA the rover's coordinates, leaving its bounty in place until the agency can pick it up.

The idea to sell this haul so cheaply came to Cyrus when he and his colleagues heard that NASA was seeking to purchase lunar rocks from private companies that were already headed to the moon. The lowball bid – to sell a scoop for $1 – was about attracting attention and starting a conversation about the long-term future of business in space. Meanwhile, the company is making its real money in the short term by selling slots on its rover for other companies' hardware. One customer is the smartphone company Nokia, which hopes to test high-bandwidth communications on the moon.

There are still many outstanding questions about how business will work up there, and academics are trying to iron them out. Masson-Zwaan was a co-founder of the Hague International Space Resources Governance Working Group, which included members of spacefaring nations, universities, intergovernmental organisations and private businesses. In 2019, it published a set of recommendations on how to achieve equitable and sustainable use of space resources. Some of its proposals, such as establishing safety zones around mines, have already found their way into the Artemis Accords.

> **"OWNING SPACE RESOURCES ISN'T ILLEGAL. BUT YOU NEED REGULATIONS SO IT ISN'T A GOLD RUSH"**

The Hague group has since disbanded. But last August, COPUOS created a subcommittee called the Working Group on Legal Aspects of Space Resource Activities with a formal, five-year mandate to iron out the remaining questions surrounding governance of space resources. While its recommendations won't be legally binding, they could be used as guidelines for laws enacted in different countries regarding resource extraction.

Perhaps the biggest sticking point will be how to ensure the benefits of space mining are equitably shared. The Outer Space Treaty says any use of space resources "should be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development". But it is unclear how this ought to work. One previous suggestion has been that nations using moon resources should somehow compensate lower-income nations for the privilege. At the Hague group, all parties agreed that this compensation didn't have to be monetary, says Masson-Zwaan. It could include things like higher-income nations investing in research and building capacity for others.

Whatever happens, most observers expect that future generations will look back at this point as the time when governance and commerce in space really began to take shape. "It's an exciting time, and it will go down in history," says Masson-Zwaan. "It's important that we get things right." ▮ **Adam Mann**

NABIL NEZZAR

The language puzzle

Gillian Forrester tries to flummox gorillas to discover how language evolved and why humans are the only animals with complex speech. She tells Alison George what she is learning and how it shines a light not just on the past, but on present-day linguistics too

IT LIES at the centre of human experience, and yet how our incredible capacity for complex language arose is a mystery. We are still far from understanding why we are the only living ape with such a skill.

Answering these questions is difficult, not least because speech doesn't leave its trace in the fossil record. However, we can look to our ape relatives for clues, as cognitive scientist Gillian Forrester at Birkbeck, University of London, is doing. She has developed puzzle mazes for chimpanzees, gorillas, orangutans and children that shed light on one idea of how language evolved. She tells *New Scientist* how her findings are challenging our understanding of the brain and painting a clearer picture of how language began.

Alison George: What inspired you to study the evolution of language?

Gillian Forrester: I've always been intrigued by the efforts to teach chimpanzees to speak, which were going on while I was growing up in the 1980s. They were a massive failure when it came to chimps learning to combine words into more complex phrases.

This got me intrigued about the common factors between human language and other animal communication systems, and how and why a language system emerged in humans but not for other great apes.

How do we start to answer that question?

We don't have our ancient ancestors to look at to see how things changed over evolutionary time because they are all extinct, and cognition doesn't fossilise. So all we can do is make suppositions based on their artefacts, such as tools and things they were buried with, to give us an indication of their communication skills.

How can studying the anatomy of great apes help?

We are great apes too. We are tool users and so are they. And we have a particular kind of brain anatomy that we share with other great apes. There is an area of the brain called Broca's area, which supports speech production. For a long time, we thought this was unique to humans, but we now know that other apes also have it.

So there's a question about precursor behaviour: what were we using this bit of the brain for, initially, that we now use for language? If we understand that, then we might have some clues about what kinds of behaviours supported language emergence over evolutionary time.

What do we know about this brain region?
One of the things that we've found in humans is that Broca's area, which is active for speech production, is also active during structured motor actions, particularly those involved in tool use and tool making – things that have to be done in a sequence to reach an end goal.

Think, for example, about making a sandwich. There's a hierarchical structure to the task, an ordered sequence of events that have to happen. This "syntax" is exactly the same sort of structured sequence that we find in language. To get a sentence out, you have to put the words in the right order. But there is also physical syntax in the way we solve problems with our hands: you have to make the sandwich in the right order to ensure the bread is on the outside.

So there is a link between our hands and our mouths?
Yes, tool making and solving problems with our hands and speech share very similar brain processing. There are highly overlapping areas that generate those behaviours. Neuroscience now highly supports that. And this exists for a reason, because we think that bit of the brain that we use for language didn't emerge for language specifically – it originally emerged for motor action sequences.

This is the idea behind the tool use theory for the evolution of language that was proposed in the 1990s. Maybe tool use was the precursor behaviour that set the brain up for language.

How did language evolve from tool use?
The idea is that our hands were initially our communication system. There is quite a lot of evidence to suggest that we originally "talked" not with our mouths, but with our hands. Then, when ancient humans became bipedal about 4 million years ago, our hands were freed and we started doing more sophisticated tool making and tool using.

But if you were using tools and wanted to share that information with other people, there was competition between these two activities, and this created a pressure for our communication to move to another modality: speech. But we don't have much hard evidence for this.

NewScientist Live

Gillian Forrester will be speaking about the emergence of modern human language at New Scientist Live on 8 October. Join us at the world's greatest festival of science at ExCeL London from 7 to 9 October and online

newscientistlive.com

How can we test this idea?
We are trying to tease this apart using maze puzzles. These represent components of human language – a physical syntax. The simplest one is called the flat maze, where you just push a nut through holes. This is like a concrete noun: you always have your finger on the nut, so you know where you are. Next we have a puzzle with a single cog, so you can't touch the nut directly but can spin the cog – and that's kind of like an action word, like our verbs.

Then we have boxes that have double cogs, where you can use the bottom cog to spin the top cog to move the nut. This is one layer of abstraction, like how adjectives act upon nouns, for example. They're a modifier, so you have to understand the relationship, the mechanisms to move the nut and achieve the goal. Then we've got more complex boxes, that are comprised of the components from the smaller boxes, which are like sentences. If you don't follow the rules for them, the nut will get stuck in a trap and you won't get it as a reward.

So these puzzle boxes represent the basic components of language in physical form?
Yes. We wanted to test if great apes could solve the more complex puzzles, hence the more complex syntax. This would give an indication of whether we inherited this physical syntactical capability.

We've worked with gorillas, chimpanzees and orangutans in captivity. We didn't know they would be able to solve physical syntax at all, and several people who work with apes told us there's no way that the apes were going to be interested or able to solve them. That was absolutely incorrect.

Are you testing it on humans too?
Yes, the second part of the study is to test the puzzles on children between the ages of 2 and 5, who range from single-word users to those who can speak in full sentences. The hypothesis is that the level that they can solve these puzzles – whether it's nouns, phrases or sentences – should be linked with their current language ability.

What have you found?
All four great ape species (gorilla, orangutan, chimpanzee and children) had at least some individuals who could solve all of the boxes. The fact that some apes can solve the most complex puzzles suggests that we inherited the syntax-processing capability from the last common ancestor we shared with chimpanzees. In children, preliminary analysis suggests a close relationship between the ability to solve the different levels of complexity of the puzzle boxes and language ability, suggesting that the boxes do work as a physical proxy for syntax structure. Together, these findings suggest that our language syntax ability didn't emerge for language specifically, and it didn't arise within the human lineage after we split from the last common ancestor.

Do you think these boxes could also be used to understand language development in children?
This investigation provides tangible evidence that these specially designed puzzle boxes reflect a physical form of syntax that is similar to the internal syntax that underpins language.

This is important because it could lead to new ways to study child development. Fine motor movements are just so tangled up with our language processing. There is a strong association between a child's manual motor ability and their subsequent speech, so, yes, there's potential to diagnose conditions earlier.

We are speaking over Zoom, and I can see a beautiful painting of a gorilla on your wall.
That's Tibs, one of the gorillas I study. She's the cleverest gorilla. She solved the puzzle boxes first. She even managed to make a tool to extract all of the nuts that were hidden in the trap. ■

Alison George is a feature editor at *New Scientist*

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Puzzles
Try our crossword, quick quiz and logic puzzle p53

***Almost* the last word**
Why are we the only "hairless" mammals with pubic hair? p54

Tom Gauld for *New Scientist*
A cartoonist's take on the world p55

Feedback
Snore scores and a standards fair: the week in weird p56

Twisteddoodles for *New Scientist*
Picturing the lighter side of life p56

Science of gardening

Leaf things to nature

Autumn leaves provide a free and easy way to make leaf mould, a useful growing medium and soil improver, says **Clare Wilson**

Clare Wilson is a reporter at *New Scientist* and writes about everything life-science related. Her favourite place is her allotment @ClareWilsonMed

What you need

Black plastic bin bags
A garden fork
Storage space
Autumn leaves

Science of gardening appears every four weeks

Next week

Science with children

WITH the dry summer the UK has had, some trees are already shedding their leaves. To me, that means one thing: leaf mould. This unappealingly named substance, made by collecting autumn leaves and letting them rot for a year or two, can be used as a growing medium and soil improver and is easier to make than garden compost.

Compost heaps are a great way to get rid of garden and kitchen waste, but they take work to build up and feed with the right mix of materials, and turning them over can be heavy going. Dry autumn leaves, though, can be collected in just a couple of hours.

As leaves turn brown in autumn, the tree is reabsorbing many of their nutrients. By the time they fall, they have a much higher carbon content relative to nitrogen than fresh leaves do. This means that autumn leaves can't be broken down by the bacteria that feast on green garden waste, and are instead broken down by fungi.

Dry autumn leaves therefore take longer to rot than fresh leaves, which is why it isn't a good idea to add them to compost bins in large quantities. But, once collected, you can more or less leave them to it.

If you have the space, you can build a small cage for storing the leaves, using chicken wire for the walls and a post at each corner. An easier option is to store them in black plastic bin bags.

DEBORAH VERNON/ALAMY

Leaves from most deciduous trees are fine, but bigger and thicker ones, such as those from horse chestnuts, take longer to decompose. One solution is to shred them before bagging. If the leaves are lying on your lawn, run your lawnmower over them and tip the grass box straight into the bin bags. It doesn't matter if some grass clippings are mixed in.

I have previously "harvested" leaves from the street, where they were conveniently swept into piles. But don't take them from busy roads in case they harbour pollutants. Nor should you take leaves from forests – the woodland soil needs them more than you.

Fill the bags about three-quarters full and dampen the leaves with water if they are dry. Tie the top, then stab with a garden fork so air can get in. You can help the decomposition by shaking the bags a couple of times per year.

It takes a good two years for the contents to rot down into leaf mould, which is a dark-brown, crumbly and light-textured substance. Once sieved, it is good for sowing seeds in, unlike home-made garden compost, which would be too dense. For potting on young plants, mix one part leaf mould with one part garden compost and one part horticultural sand.

If you can't wait so long, after one year you can use the partly rotted leaves as a general soil improver or an organic mulch, a substance used to cover the soil around the base of plants to reduce moisture loss and keep down weeds. ▮

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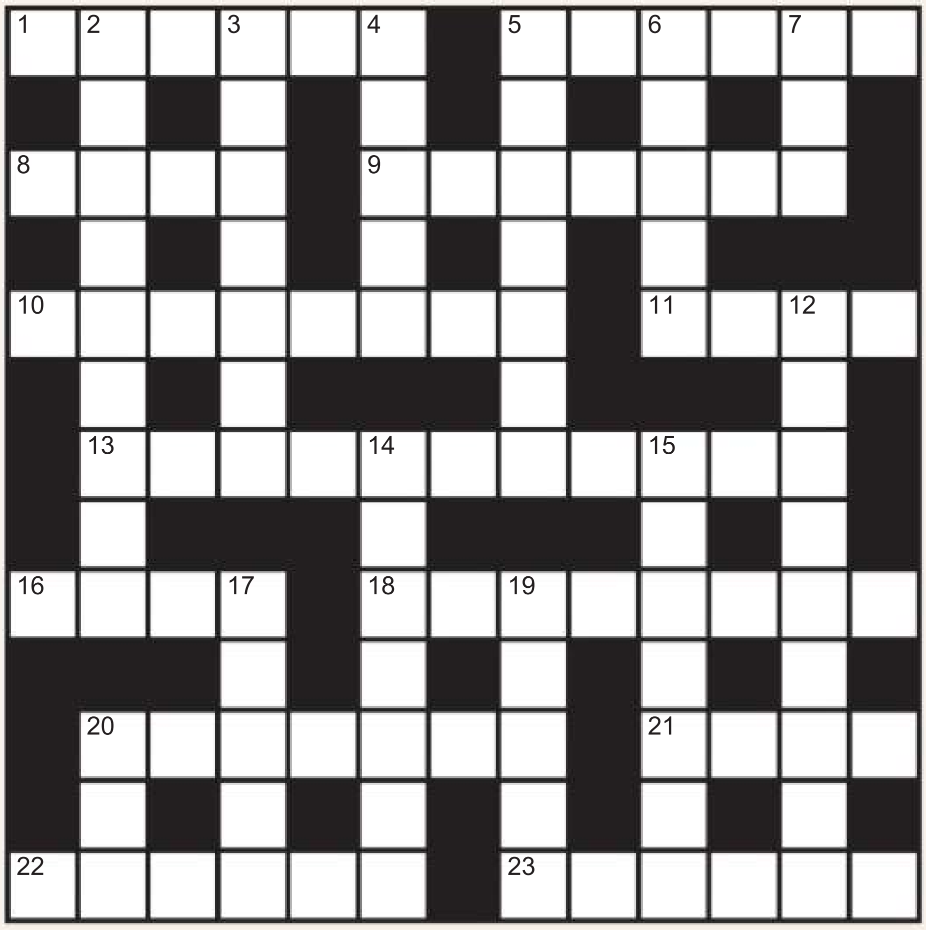
Cryptic crossword #92 *Set by Rasa*



Scribble zone

Answers and the next quick crossword next week

ACROSS

1 Use a particular method to get down six-pack, then lie back (6)
5 Lizards hide near outskirts of Knossos (6)
8 Computer expert seen in Whitechapel (4)
9 Go and get biologist's building block left in child's bed (7)
10 Cartography innovator essentially tore after fish-feline hybrid? (8)
11 Park east of total cesspool (4)
13 Solicit opinions of one country worker's contribution to the ecosystem (11)
16 Royal residence lacks soothing stuff to be taken by mouth (4)
18 Vera doesn't finish opening wine (8)
20 Metal: try it out with sound of hesitation (7)
21 Reportedly employ females on the farm (4)
22 French physicist's mother returning to father in Paris (6)
23 Steals new graduate's adornment (6)

DOWN

2 Apiarist's shriek interrupting paging device (9)
3 Upright crystals initially buried in shattered halite (7)
4 Allowed one-third of citations supporting pair of lithologists (5)
5 A sailor renovated sunrooms (7)
6 Tabloid couples met up in central Pakistan (5)
7 Tackle young ferret (3)
12 For example, platypus egg not right in viral internet thing (9)
14 Bill favoured by state (7)
15 US auditors confiscating a vague amount of pentane and neopentane, say (7)
17 Hot drink overdue, taking extra time (5)
19 Send baker's gadget in lift (5)
20 Vegetable Month coming up (3)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #169

1 Salpingitis is inflammation of which part of the body?

2 The banana equivalent dose is an informal measurement of what?

3 Which of these space telescopes was launched first: Uhuru, Hipparcos or Ariel V?

4 The root of plants in the *Panax* genus, popular in traditional medicine, is better known as what?

5 Do baryons, a type of subatomic particle, have an odd or even number of quarks?

Answers on page 55

Puzzle

set by Mary Ellis

#185 Cheque out

Eccentric Aunt Marion has given up buying presents for her nephew Matthew and has decided instead to gift him the annual interest she earns on her building society account. She hands him a cheque.

Matthew has never seen a cheque before and doesn't have a bank account, so his aunt tells him to go and cash it at a post office for notes and coins.

But the cashier is clearly as baffled by cheques as Matthew, because in producing the cash, she switches the pounds and pence. Matthew sticks the money in his empty wallet without counting it and heads out to treat himself to a burger that costs £7. It is only then that he counts how much cash he has left. Remarkably, it is exactly twice as much as the figure on the original cheque. It is almost as if he has a magic wallet.

How much does he still have available to spend?

Solution next week

Broken clouds

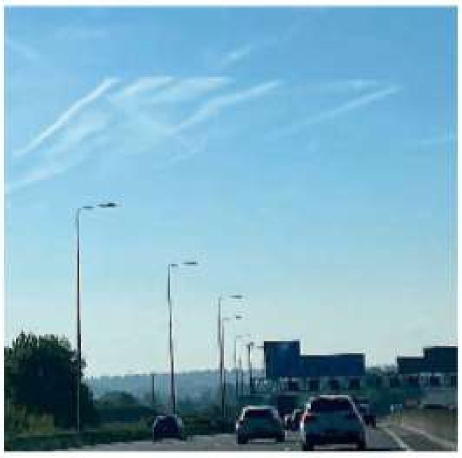
The image (below) is of the morning sky over London one hot day in June. Why do the contrails end so evenly and abruptly?

David Muir
Edinburgh, UK
Condensation trails, or contrails, are formed when the water vapour present in the exhaust gases of aircraft undergoes freezing or condensation.

In the atmosphere, regions of air can differ in temperature, humidity and density, and this is in a constant state of flux. Warm, lighter air can ride up over cold, heavier air, and cold, heavier air can drive underneath warmer, less dense air. This is very clear during storms and hurricanes.

When planes are flying through relatively moist air, contrails last for a longer time. When they fly through dry air, contrails remain for a shorter time because they rapidly evaporate.

The contrail picture in question captures an occasion where planes have been flying through invisible boundaries that sit between moist and dry air. This leaves contrails that end abruptly and look like giant dashes in the sky.



Chris Daniel
Colwyn Bay, Conwy, UK
A contrail is produced when a jet engine's exhaust gas – mainly the water vapour – freezes. This creates a linear cloud.

While contrails are usually continuous, they can be intermittent (as is the case in the picture) if the air temperature and humidity varies across their lengths.

This appears to be a single, discontinuous contrail, spread in the direction away from the camera that captured it. I can tell this has occurred because the upwind edge of the contrail is sharp and well-defined, while the opposite edge is smeared.

A less likely explanation for this patterning is that the picture contains contrails that were formed by several aircraft travelling in formation towards or away from the camera.

Natalie Roberts
Watford, Hertfordshire, UK
Contrail is an abbreviation of "condensation trail", which gives a clue as to how these human-made lines in the sky form. When a jet engine is running, it produces three common emission products: water vapour, carbon dioxide and a soot made of incompletely burned hydrocarbons. The water vapour from the jet engine, along with the water vapour already present in the atmosphere, can cluster around the soot particles, which act as condensation nuclei. Essentially, soot particles become catalysts for droplets of water or ice crystals to form rapidly.

The regular, parallel nature of the contrails in the picture can be explained by the fact that commercial airplanes all use the same flight paths, especially when travelling in and out of airports. They also land and depart at regular intervals. The contrail lines in question aren't actually sitting within a flight path, but instead have all been blown away by a steady wind.

It is just like dropping ping-pong balls into a stream at regular intervals, all from one place. You will get a line of balls floating away, not a pile in front of you.

The sudden disappearance of the contrails can be explained by another feature of airplanes: they travel high in the sky, but ascend from and descend to airports. As the atmosphere's make-up isn't homogeneous, planes will cross layers of air that have different temperatures, humidities, wind speeds and wind directions.

These contrails appear to have formed in a windy layer of humid air, before the rising or descending planes entered a layer of much dryer air. This caused the lines in the sky to end abruptly.

JONATHAN KNOWLES/GETTY IMAGES

How quickly would a person need to be travelling in order to run on water?

This week's new questions

Running water **How fast would you have to travel to be able to run on water?** ***Philip Welply****, St Albans, Hertfordshire, UK*

Moonlit life **Without moonlight (i.e. if our moon was non-reflective or black, but with exactly the same gravity and motion), would life on Earth be any different?** ***Jakob Kaye****, Auldgirth, Dumfries and Galloway, UK*

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Hairy issue

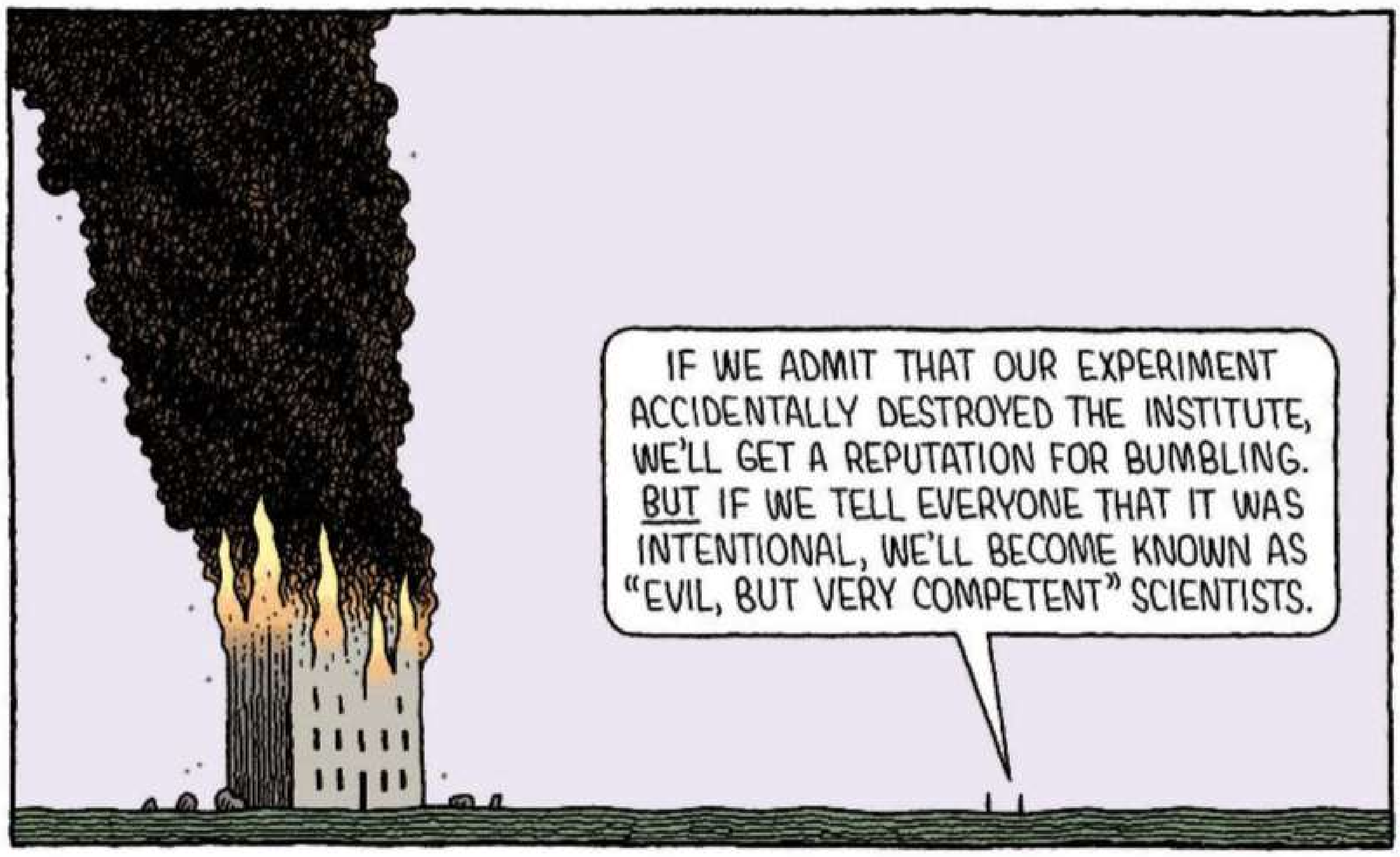
Why do humans have pubic hair, when other "hairless" mammals, like pigs and elephants, manage without it?

Tony Cooke
Gunning, New South Wales, Australia
I think humans have pubic hair because of the structure of the human pelvis and the position of the genitals: people's thighs tend to rub together when they walk. Pubic hair reduces the friction between the skin surfaces that would otherwise chafe.

This becomes apparent if you remove some of your pubic hair. A small reduction in pubic hair will result in the skin of the groin sticking together, particularly in warmer weather. The same idea applies to the armpit, where a patch of hair also grows.

Other animals, such as elephants, have different anatomies, with their legs tending to be more separated from each other. Thus, their legs don't rub together to the same extent, reducing the need for pubic hair.

Tom Gauld
for New Scientist


IF WE ADMIT THAT OUR EXPERIMENT ACCIDENTALLY DESTROYED THE INSTITUTE, WE'LL GET A REPUTATION FOR BUMBLING. BUT IF WE TELL EVERYONE THAT IT WAS INTENTIONAL, WE'LL BECOME KNOWN AS "EVIL, BUT VERY COMPETENT" SCIENTISTS.

Their legs are also often at right angles to their bodies, and so the area of contact between their legs and bodies is low.

Matthew Stevens
Sydney, Australia
I propose a hypothesis that relies on the evolutionary history of our ancestors in the grasslands of Africa. The brief explanation is that, in becoming essentially hairless and upright, our ancestors could more effectively hunt down prey in grasslands.

But they acquired greater agility at the cost of an increased risk of injury to the reproductive organs resulting from collision with grasses, many of which have sharp seeds and razor-edged leaf blades. A wiry mat of hair will deflect sharp grasses away from the vagina's entrance, for instance. As well as surrounding pubic hair, the penis has evolved a foreskin for protection.

Ellen Bolton
Millmerran, Queensland, Australia
Perhaps humans developed pubic hair in order to deter smaller things, such as insects, as well as bigger things from entering our private parts.

> **"Our mostly hairless, upright ancestors acquired agility at the cost of an increased risk of injury to the reproductive organs"**

Wrong odds

Why does an even number feel "right" but an odd one "wrong" when, say, I'm setting my TV volume control? Am I alone in this? (continued)

Mikhal Ben-Shaprut
Eilat, Israel
My feeling is that it results from humans seeking both balance and symmetry. In terms of balance, we feel safe and solid if we are standing on two feet, but less so standing on one foot. People also generally prefer bicycles to unicycles and four-wheeled vehicles to three-wheeled ones.

We are also used to having symmetrical pairs of limbs, eyes and ears. In particular, when it comes to definitions of beauty, we almost always refer to symmetry. We can also see this preference in fashion, where hems, sleeves and trouser legs tend to hang evenly. In the same vein, even numbers instinctively feel more "right".

Paul Mundy
Witham, Essex, UK
As a pensioner, the only number of relevance with regards to TV or radio volume is that which allows me to hear the programme being broadcast. When your younger readers reach later life, the same will apply to them, and the odd or even nature of the numbers will be irrelevant.

Robert Stuart
Halifax, Canada
It is because pairing is essential for survival. This may be a pair of parents or a parent and their child. Meanwhile, a third party is suspected as a threat. ▮

Answers

Quick quiz #169
Answers

1 The fallopian tubes
2 Exposure to ionising radiation
3 Uhuru, which launched in 1970
4 Ginseng
5 An odd number

Quick crossword #116 *Answers*

ACROSS 1 Female, **4** Aneurism, **10** Adipose, **11** Tar sand, **12** Cuff, **13** Automatons, **15** Uranus, **16** Neptune, **20** Desktop, **21** P-value, **24** Futurology, **26** Esso, **28** Everest, **29** Nitrate, **30** Tank Girl, **31** Sphere

DOWN 1 Francium, **2** Mainframe, **3** Loop, **5** Nitrogen, **6** Unreactive, **7** Imago, **8** Medusa, **9** Venus, **14** Zuckerberg, **17** Null-space, **18** Collator, **19** Kerosene, **22** Effect, **23** Agent, **25** Treen, **27** Step

#184 Cipher sum
Solution

We can denote the sum as: ABCDE + EBEBA = DAFCB. Note that the first and last columns involve addition of A + E, but add to different numbers, which means that B + B must be > 10, with 1 carried to the next column to the left. In other words, D = B + 1, and B > 6. B can't be 9, as it would mean that D has to be 10, and can't be 8 because that would mean D = 9, so C would be 7 (fourth column), but that rules out any options for F. That leaves B = 7, so D = 8 and C = 5, which leads to:

$$\begin{array}{r} 47583 \\ +\,37374 \\ \hline 84957 \end{array}$$

Standard issue

World Standards Day 2022 will soon be upon us. The public's enthusiasm for this annual bifurcated event, which celebrates the technical rules and regulations that keep society running, seems undimmed by the covid-19 pandemic.

The bifurcation is geographical. This year, most of the world will celebrate World Standards Day on 14 October. This date is specified by a consortium of three groups: the International Organization for Standardization, the International Electrotechnical Commission and the International Telecommunication Union. The goal is to recognise the importance of international standards.

Meanwhile, the US Celebration of World Standards Day will take place on 13 October. Its date is specified by the American National Standards Institute (ANSI) and the official theme is "Sustaining the U.S. Standards Model and American Standards Leadership".

The world, the US included, began celebrating World Standards Day in 1970. In some years, the US has a World Standards Week. Usually, none of the dates of the country's World Standards Week coincide with the date of the world's World Standards Day. The innovation continues.

This year, the US celebrates two World Standards Weeks. ANSI's website says the first happened on 17 to 19 May (thus officially a three-day week), and the second will happen on 10 to 14 October (five days). Elsewhere on its site, ANSI says the second week will span 10 to 13 October (four days). Confusion is a standard in this world.

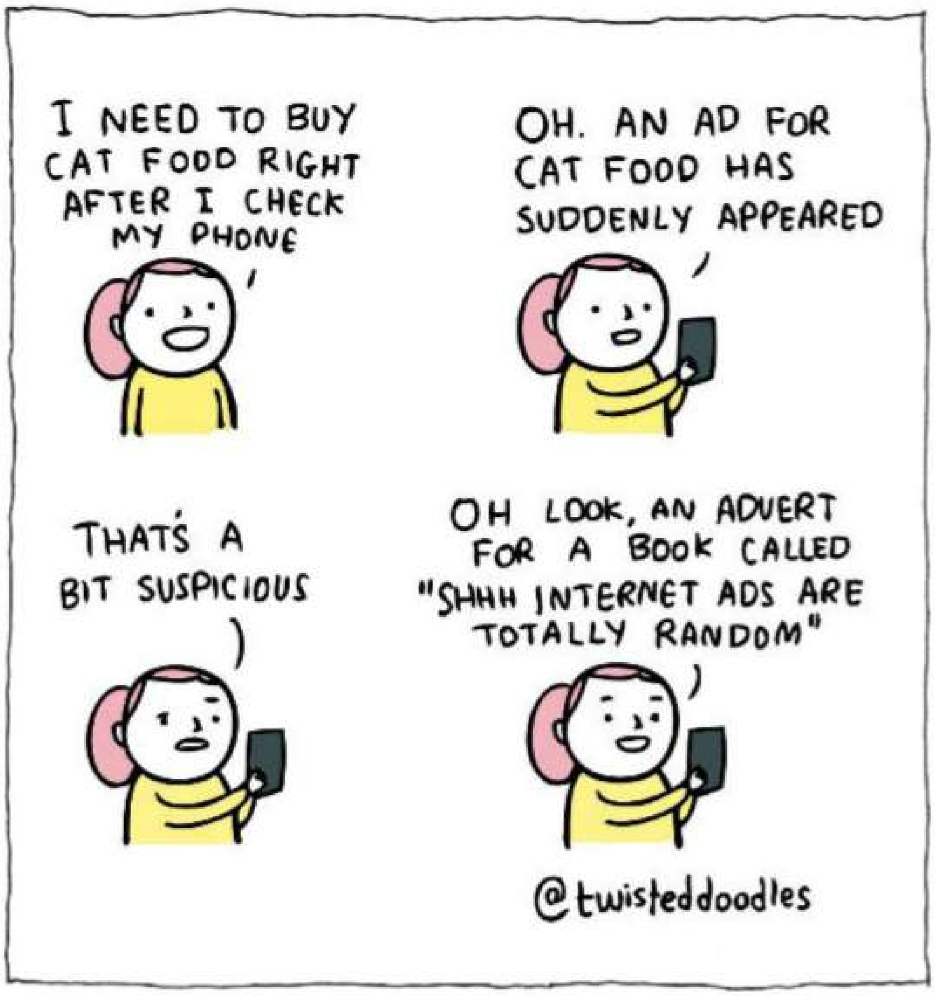
When to add the teabag?

We invite you, if you are a right-thinking tea drinker, to join us in the most proper imaginable ritual of celebrating World Standards Day. At the stroke of 4pm, heft and enjoy a cup of tea. That is provided, of course, that you or a trusted one has prepared the cuppa in accordance with the official British tea standard, BS ISO 3103:2019: "Tea. Preparation of liquor for use in sensory tests".

Copies of BS ISO 3103:2019 can be purchased from the British Standards Institution for £138. (Note: members of the British Standards Institution can obtain it at half price, a mere £69!) Also note that while "addition of milk is not essential, it sometimes helps to accentuate differences in flavour and colour".

Five pages long, the standard has been updated from earlier versions as the UK worked to maintain its leadership position in an unstable world. The best-known of those earlier versions, BS 6008:1980, was awarded the Ig Nobel Literature Prize in 1999.

Twisteddoodles *for New Scientist*


I NEED TO BUY CAT FOOD RIGHT AFTER I CHECK MY PHONE
OH. AN AD FOR CAT FOOD HAS SUDDENLY APPEARED
THAT'S A BIT SUSPICIOUS
OH LOOK, AN ADVERT FOR A BOOK CALLED "SHHH INTERNET ADS ARE TOTALLY RANDOM"
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Publication day

Feedback was recently present at a relaxed discussion between a physics professor and a psychology professor. Both had been among the speakers at a public event earlier that day.

The physicist said (this is a paraphrase, as no one was taking notes): In my field, when a new study is published, everyone gets excited and immediately tries to figure out what is wrong with that study. But I notice that in psychology, things seem to work in a different way.

The psychologist replied: Very different. In my field, when we see a new study, everyone gets excited and tries to figure out how to build on this new knowledge.

Discuss, if you like (being careful to supply clear examples, and to point to documentation thereof).

Snore score

It can be annoyingly difficult to measure how annoying a person's snoring can be. Researchers at the University of Regensburg, Germany, offer up a solution: "An objective statement about the annoyance of snoring can be made with the Psychoacoustic Snore Score (PSS). The PSS was developed based on subjective assessments and is strongly influenced by observed sound pressure levels."

Their assessment of how to assess snoring appears in the study "Are Annoyance Scores Based on Sound Pressure Levels Suitable for Snoring Assessment in the Home Environment?", published in the journal *Sleep and Breathing*.

This kind of work isn't easy to do well. There are complexities, such as the example mentioned by the Regensburg team: "In a study on the sleep quality of women living with snorers, Blumen et al. had to exclude 7 out of 23 couples. The reason was that the women themselves snored to a relevant extent."

Much confusion arises, they suggest, from the interplay of the snoring with whatever other annoying sounds happen to be in the air. They list some noises that, when heard in symphony with a snorer, often prove most annoying: garbage collection, stormy weather, a bell ringing.

The study also looks back at earlier work that aimed to classify the range of potential annoyance posed by a snoring bed partner: "The Snoring Spectrum: Acoustic assessment of snoring sound intensity in 1,139 individuals undergoing polysomnography", published in *Chest* in 1999.

That research – done at the University of Minnesota, the Dortmund Sleep Disorders Clinic in Germany and elsewhere – claimed to reveal a discrepancy concerning sex: "The average levels of snoring sound intensity were significantly higher for men than for women." Discuss at your peril.

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SPEEDMASTER CANOPUS GOLD™

Launched in 1957, the Speedmaster earned its nickname in 1969, when it became the first watch worn on the moon. This edition, while retaining the chronograph's classic design elements, features a rarely used sun-brushed silvery step dial and is cased in OMEGA's exclusive 18K Canopus Gold™. A unique white gold alloy with high brilliance, named after an extremely bright southern star used for centuries as an important reference point for explorers - and still used today by space agencies. This striking timepiece is also a Co-Axial Master Chronometer, independently certified by the Swiss Federal Institute of Metrology (METAS) to guarantee the highest levels of accuracy, reliability and supreme resistance to magnetism on Earth and in space.

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